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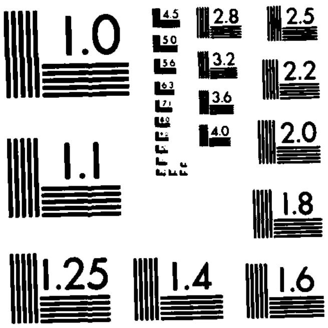

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ANALYSIS OF DOD TRAVEL MANAGEMENT:
AN APPLICATION OF
LEARNING CURVE THEORY

Silvia Signars Anderson, 1st Lt, USAF
Robert F. McCauley, Capt, USAF

LSSR 72-82

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The recent Congressional interest in the DOD travel management program mandates improved methods of managerial control. This thesis applies learning curve theory, a traditional production planning tool, in forecasting 1983 discount fare usage at selected Scheduled Airline Traffic Office (SATO) locations. These projections may serve as criteria for comparison of future Travel Management Services Program (TMSP) test data. The authors cite the following potential benefits in learning curve applications to travel management: (1) improved cost control; (2) realistic goal establishment; (3) accurate cost prediction; and (4) improved budget estimation. The authors also provide a comparative analysis of the service differences between the enhanced SATO and the TMSP.

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ANALYSIS OF DOD TRAVEL MANAGEMENT: AN APPLICATION OF LEARNING CURVE THEORY

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

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In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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Thomas C. Harrington
COMMITTEE CHAIRMAN

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CHAPTER I

INTRODUCTION

Overview

The recent emphasis on efficiency and careful money management by the American public and their elected representatives at the federal and state levels requires a reexamination of costs in all facets of government activities. Travel by government employees is one of the most highly visible activities and, consequently, the expenditures for travel demand the attention of elected officials. An examination of travel costs requires the study of two major areas. Initially, this study must determine the costs of travel. Through the use of learning curve theory, it is proposed that travel management activities (for definition of this term and others, see Appendix A) estimate the future costs of travel for government officials. This would enable these officials to budget for future travel activities, and to determine what travel costs should be. The second major area of study involves the nature of travel management. An examination of the travel management activities should reveal the effectiveness of cost control in this facet of government operations.

Learning Curve Theory

Learning Curve Theory provides a quantitative tool by which corporations price production units, enact make or buy decisions, and purchase major acquisition systems. Largely used in the production and system acquisition environments, learning curve theory emerged from the production of aircraft in the 1920s. T. P. Wright reported the cost volume relationship typified by the learning curve in an article published in 1936 (58:122-128). The learning curve gained its popularity during World War II in major defense acquisition projects such as shipbuilding and aircraft production (5:88). After the war, commercial industry adapted the learning curve to the production of appliances, and other manufactured items.

As discussed above and in more detail in Chapter III, learning curve theory has been used primarily in the production and manufacturing environment. One of the major objectives of this research is to demonstrate the effectiveness of the learning curve in the service environment. Further learning curve theory provides an approach or structure from which to study service pricing or alternative decision problems. Examination of this aspect of learning curve theory will be accomplished in Chapters V and VI.

Travel Management

During 1981, the federal government spent four billion dollars on travel (39:1). The Department of Defense (DOD) share of this expenditure was 65 percent (39:1). A General Accounting Office (GAO) report published in July 1978 found "Federal employees travelling on government business frequently had not taken advantage of available discount fares." As a result, the federal government incurred a commercial air travel cost significantly higher than necessary. This GAO report presented numerous examples of travellers not using discounts such as excursion, group, or off-peak fares, even though these fares were readily available and would not interfere with agency business. Four examples of governmental waste discussed in the GAO report are illustrated below.

1. The Federal Aviation Administration unnecessarily spent as much as $312,000 for the air travel of employees attending centralized training courses in Oklahoma by failing to use excursion fares.

2. The DOD spent $230,000 in excess of excursion fares, while sending reserve trainees to two-week training sessions.

3. The Environmental Protection Agency lost the opportunity to save $357 by failing to use a group fare to a conference in Salt Lake City, Utah.

4. The Department of Energy (DOE) sends its employees to Washington National Airport, across the river in Virginia, to catch flights to Philadelphia and New York. Yet the Union Station's Metroliner is just a block and a half from the DOE office. The GAO report calculated the average travel time between Washington and Philadelphia, allowing for taxi rides to the terminals, as two hours and twelve minutes by train, and three minutes longer by air. The air fare cost is more than twice the cost of the train fare (55:ii).

In a memorandum to the Heads of Executive Departments and Agencies, President Ronald Reagan addressed the issue of management inefficiencies and wasteful spending causing the cost of travel to increase. Through this memorandum, President Reagan directed the following changes to be made to federal travel policies and practices.

1. Separate travel regulations for civilian employees, foreign service, and uniformed services will be simplified, standardized, and updated to assure consistent treatment of all federal travellers.

2. Travel authorization policies will be tightened, including a reduction in the use of general travel authorizations.

3. Travel services for agency employees will be improved at headquarters and principal field locations,

including greater use of commercial ticketing and travel services, and available discounts.

4. Greater efforts will be made in cooperation with the travel industry to expand the availability and use of transportation, lodging, and other travel related discounts for federal travellers.

5. Travel reimbursement policies will be streamlined to include adoption of locality-based flat per diem rates for subsistence costs, improved controls over travel advances, and simplified voucher processing (39:2).

Implementation of these recommendations is expected to provide a cost savings of over $200 million, which includes a cost avoidance of $116 million in direct travel expenditures and a savings of over $85 million in administrative costs (see Appendix B) (50:180).

The GAO report discussed above provided three reasons why federal employees have not obtained the lowest available fares. They are: (1) employees did not know special fares existed; (2) employees did not make airline reservations sufficiently in advance to qualify for reduced fares; (3) no agency was responsible for making group reservations for federal employees attending multi-agency conferences, or for employees of various agencies who routinely had common departures and destinations (55:5).

Shortly after publication of this GAO report, the Deputy Assistant Secretary of Defense established the

Framework for Reservation and Ticketing Service (FRATS) working group. The group was tasked with the development of improved passenger routing, reservation and ticketing procedures within the DOD.

The FRATS working group studied alternative approaches for improving air passenger routing, reservation and ticketing procedures; developed guidelines for use by individual activities in selecting the optimum reservation and ticketing service to meet their needs; produced a set of standards covering the product characteristics most desirable in any electronic reservation and ticketing service; and developed a uniform bilateral agreement to be negotiated with industry representatives to guide operations of commercial ticketing offices on defense installations (52:1).

Subsequent to the birth of the FRATS group, each of the military departments was independently testing different approaches to government travel management. The Air Force concept of reservations and ticketing relied primarily on services provided by the Scheduled Airline Traffic Office (SATO). In 1979, the Air Force automated the SATO under the enhanced SATO program (43). This enabled the Air Force to take advantage of airline reservations and ticketing systems in a real-time environment. The enhanced SATO also provides monthly management reports allowing cost center managers to better control travel costs. The enhanced SATO program affected a closer association, both physically and operationally, between the SATO and the traffic management offices, as well as with the accounting and finance travel and the personnel orders sections. This closer association of the four activities enables the military member to prepare for a temporary duty assignment at one central location.

The Army initially challenged the basic SATO concept, which has been in existence for over twenty years, with their Standard Travel Advanced Reservation System (STARS) in 1979. While STARS was later renamed as the Travel Management Services Program (TMSP), the Army proposal remained the same. This proposal suggests the use of local, privately owned travel agencies and independent airline travel agents in addition to the SATO. The determination of which commercial travel manager would be used would be made by individual military installations. The challenge to the enhanced SATO program by the TMSP constitutes the alternative decision problem referenced in the learning curve theory portion of this chapter.

Statement of Problem

This research focuses on: (1) applying the learning theory to a service-oriented industry, and (2) the efficient spending of Air Force air transportation dollars via commercial carriers.

The learning curve theory has been typically used in a high volume, high cost, complex production environment. This research attempts to determine the usefulness of the learning curve as an evaluative tool in the service environment.

Further, the problem centers around the efficient spending of commercial air passenger transportation dollars. In particular, this facet of the problem requires a management decision regarding the use of a private carrier-sponsored Scheduled Airline Transportation Office (SATO) versus an independent travel agency. Within this determination lies the nature of future air passenger transportation cost control.

Justification

The need for efficient spending and effective cost control has been mandated by the legislative and executive branches of the federal government. In July 1981, the Senate Committee on Governmental Affairs' Hearing on Travel Management highlighted the legislative branch's concern over the administration's travel management program (50:1-4). As mentioned above, the executive branch spends approximately four billion dollars on travel annually, 2.7 billion dollars of which is spent in the Department of Defense (50:2,9). Consequently, there is a strong focus on the Department of Defense and its efforts to reduce and streamline costs.

The Reagan Administration's drive to streamline travel costs led to what Edwin L. Harper, the Deputy Director of the Office of Management and Budget (OMB), called ". . . the most comprehensive program of travel reforms ever attempted. . . [50:31]." To facilitate these reforms the President created the Travel Management Improvement Group. This group, headed by the Associate Director of Management of the OMB, provides a forum of all federal departments leading to better cost control, feedback, and uniform travel management systems. Through the reform spearheaded by the group, the federal travel management system is expected to achieve an annual savings of 200 million dollars (50:37). Much of this savings will be attributed to the use of airline discounts and improved passenger processing methods (50:37).

Studies performed by the General Accounting Office have reflected the congressional interest to reduce travel expenditures. While the Harbridge House "Study of DOD Organization for Transportation and Traffic Management" suggests organizational and procedural changes at a higher level than this research examines, the theme of the study is the same. Both studies aim at streamlining cost, and providing the most transportation for the dollar.

A second major justification of the research concerns the upcoming test of the Travel Management Services Program (TMSP) sponsored by the Military Traffic Management Command (MTMC). This program examines the use of travel agencies, independent travel organizations, and SATOs as DOD travel management agencies. Request for proposals have been developed by all three services and sent to participating commercial travel organizations. These organizations will submit bids to perform travel services during the test period (twelve months with provisions for a twelve-month extension). The test will demonstrate the ability of agencies other than SATOs to perform transportation functions. It also institutes a total transportation program including ground transportation, car rentals, hotel reservations, and group transportation rates.

Another justification of this research pertains to the state of the national economy. The reduction of governmental spending under the supply side economics philosophy of the Reagan Administration requires all facets of governmental operations be examined. Federal travel management warrants investigation as examples of travel waste and abuse are abundant. Further, federal travel, with the exception of the DOD and the General Services Administration (GSA), has been conducted out of the purview of a central travel management agency. Outdated travel regulations add to the problem of managerial control. Due to the state of the economy, and the lack of knowledge regarding government travel expenditures, congressional reductions in government spending are aimed often at the heart of the travel budget.

Finally, the development of airline and ground transportation deregulation has rendered the manual method of travel management obsolete. Airline, rail and bus guides are inaccurate at the time of publication. Real-time automated reservation systems are necessary to determine the most economic method of travel. Airline rates on the major channels are the most competitive and demand continual attention. In this type of environment, a capable travel management agency equipped with automated reservation systems operated by trained reservation agents is crucial to an effective governmental operation.

Research Objective

The objective of this research is twofold. Initially, this study attempts to determine the predictive ability of learning curve theory as applied to travel expenditures in a service environment. This application will provide a managerial tool for developing future performance goals of the SATO, operating limits for control purposes, as well as travel budgeting criteria. Secondly, the research presents a subjective analysis between the enhanced SATO and the proposed TMSP. At the conclusion of this presentation, this study will examine the usefulness of SATO cost projections obtained through learning curve theory in establishing comparable cost criteria. Dependent on the credibility of the cost criteria obtained, the cost criteria may be used in comparison with the actual TMSP data collected during the upcoming TMSP test.

Research Question

This research attempts to answer the question: May learning curve theory be used to predict air transportation cost savings in a SATO, and establish SATO cost criteria with which to compare other travel management agencies?

Scope

This study is based on the travel requirements and operations of the United States Air Force. The results, however, may be adapted to other services.

The purpose of the selection criteria developed through learning curve projections is to aid the Air Force in its decision among two alternative methods of travel management currently available to the DOD--SATO and TMSP.

The data base is limited to the twenty original enhanced SATO bases. This group of bases was chosen to allow for the application of the learning curve theory over a substantial period of time. The time frame examined is January 1981 to February 1982.

Assumptions

The research reported in this paper is based on the following assumptions:

1. Costs are expressed in 1981-82 dollars.

2. The original twenty bases are representative of the SATO enhanced programs Air Force-wide.

3. The airline marketing system will remain intact and much like the status quo after the sunset of the Civil Aeronautics Board (CAB) for the purpose of learning curve projections.

4. Travel agencies will be reimbursed by commercial airlines through commissions on government official travel.

5. Through the projected period, services offered and provided by the SATO would remain the same. (SATO services offered under TMSP would be considered separately.)

6. Airline rates will not increase as a result of carriers paying a commission to the travel agents under TMSP.

7. Performance data for the sample enhanced SATOs are correct as received from the Passenger Division of the United States Air Force Directorate of Transportation (HQ USAF/LETTB).

8. The SATO located at McGuire AFB, New Jersey should provide comparable performance results to the travel agency operating at Travis AFB, California.

9. The learning curve plotted by unit uses the number of passengers travelling in the same month of the previous year.

Limitations

The results of the experiment(s) performed in this research effort are limited in the following ways:

1. Cost criteria provided through the learning curve theory are valid for SATOs as they provide services now.

2. The services provided by the SATO at Wright-Patterson AFB (WPAFB) are considered as standard. (A discussion of the selection of WPAFB is included in Chapter II.)

3. The model constructed for the travel agency is based on published projections.

Summary

In this chapter, the authors defined and outlined the goals of this research. The differences between the SATO and TMSP are described in detail in Chapter II. Chapter III comprises a literature review of learning curve theory and its applications. In Chapter IV, the methodology describes the use of learning curve theory, and its application to the percentage of passengers using discounted fares versus the total number of passengers. The results and the conclusions of the research are discussed in Chapters V and VI respectively.

CHAPTER II

OVERVIEW OF SATO AND TMSP

Introduction

The two methods of travel management currently available to the Department of Defense are the enhanced Scheduled Airline Traffic Office (SATO), as implemented by the Air Force, and the Travel Management Services Program (TMSP), as proposed for implementation at Travis AFB, California. An overview of each alternative is presented in this chapter beginning with discussion of the SATO.

Scheduled Airline Traffic Office (SATO)

Under a contractual agreement between the Air Force and the Air Transport Association of America, the commercial airlines are invited to establish SATOs at Continental United States (CONUS) Air Force installations. These offices are under the monitorship of the base traffic management office to insure compliance with the memorandum of understanding incorporated by the parties mentioned above.

The purpose of the SATO is to provide the lowest cost routing, including discounted and joint construction fares, on a fair and impartial basis. The SATO operation must be consistent with mission requirements and guidance furnished by the host traffic management office concerning the conditions under which discounted fares should be used. In January 1981, the Air Force initiated the enhanced SATO program to take advantage of commercially available automated reservation systems and discounted fares. The events leading to the enhancement program are discussed next, followed by a description of the key features of the program.

In 1977, the automated reservation system gained popularity in the commercial air travel industry (52:2). In January 1978, the Deputy Assistant Secretary of Defense for Supply, Maintenance and Services requested the Military Traffic Management Command (MTMC) to perform a cost-benefit study of automated airline reservation and ticketing services to determine the feasibility of adopting these services at military installations. Specifically, MTMC was asked to determine the cost effectiveness of acquiring and using Electronic Reservation and Ticketing Systems (ERTS) in lieu of SATO facilities and programs or some other procedure (48:3).

The MTMC study, completed in 1978, indicated that SATO operations were not consistent with mission requirements and guidelines furnished by the host TMO concerning the conditions under which discounted fares should be used. MTMC reported at least 36 percent of DOD official traffic was routed solely by the SATO. The study also claimed SATO's routing was biased and not always at the lowest fare. In an article entitled "Reduced Airline Fares--AFISC," TIG Brief, November 1978, the following statement was made: ". . . TMO responsibility for arranging support for official travellers (routing, flight reservations, time, etc.) must not be passed on to SATO." Statements such as this were based on attitudes shared by MTMC that, "SATOs and the airline industry in general are ineffective tools for obtaining lowest cost transportation which meets DOD mission requirements [48:4]."

Based on these findings, the MTMC study recommendation was that installation traffic management and transportation officers were to utilize, wherever possible, the Electronic Reservation and Ticketing System (ERTS) which would (1) save travel dollars through decreased reliance on SATOs, and (2) fit into a future MTMC managed traffic reservation system known then as STARS (48:4).

Disenchanted with the conclusions of the MTMC study, members of the USAF Directorate of Transportation (HQ USAF/LET) performed an on-site study of the SATO at Wright-Patterson AFB, Ohio (WPAFB), which processes over 53,000 duty travel requests per year (47).

The Air Staff Group found little evidence to support the MTMC conclusions. What the Air Staff did find was highly qualified clerks using ten cathode ray tubes

(CRTs) connected to the Delta Airline Central Reservation System. They then decided WPAFB provided an excellent opportunity and location for improving the Air Force travel management system and answering MTMC's allegations.

Seeking a means for taking immediate advantage of the automated reservation system and discount fares, the Air Force developed the enhanced SATO program. The colocation of the SATO and TMO offices was established to facilitate a closer working relationship. The enhancement also involved shifting the responsibility of travel routing from the TMO to the SATO, as well as requiring the SATO to provide the TMO a Monthly Management Summary Report which the TMO uses as a tool to monitor the SATO performance. The original contractual agreement between the Air Force and the Air Transport Association of America (ATA) was amended to explicitly state the requirement of taking advantage of "lowest" fares and SATO's responsibility to provide managerial data for evaluative purposes. This data is provided on a Standard Source Document and forwarded on a daily basis to the Service Bureau Corporation (SBC), Richmond, Virginia, by each SATO.

Two separate reports will be developed by the SBC and submitted to HQ MTMC monthly on magnetic tape. These reports are called the Monthly Management Summary Report.

> One report will show passenger movement by class of travel between city pairs. The other will provide summary revenue totals of official traffic moved between city pairs.

Comparisons of costs of SATO developed routings versus base-line Y class costs over the same routes will be summarized to determine savings through the use of discount fares. Additionally, total traffic by organization and a comparison of discount fares versus full travel as well as a summary on non-use codes for each organization will also be furnished [48:10].

The enhanced SATO program answered GAO's criticism of the failure of government agencies to educate travellers on discount fares, to document the use/non-use of discount fares, to analyze non-use of discount fares and to audit the monies spent on travel (55:5). This program also answered the criticism, stated previously in this chapter, of the MTMC study. The six-month test (1 July to 31 December 1979) confirmed that significant economies were possible through close cooperation between the TMO and the SATO. The test also demonstrated that information gathered through SATO reporting procedures was vital to the TMO in the analysis of unit travel programs.

As of April 1982, the enhanced SATO program subsequently was implemented at fifty CONUS bases. In addition, the ATA has established SATO satellite service at eighteen small bases where the traffic flow does not warrant an independent SATO.

Travel Management Services Program (TMSP)

The proposed Travel Management Services Program, formally known as the Standard Travel Advanced Reservation System (STARS), was influenced by the Office of Management and Budget Circular No. A-76 which reaffirmed the government's general policy of "reliance on the private sector for goods and services" and knowledge received from industry publications pointing to industry's increased reliance on commercial travel management firms to provide a full range of travel support at no cost to themselves (33:1). This proposal, through a contractual agreement with travel agents, seeks to use the competitive travel industry market to maximize travel support while minimizing cost to the government. The selected travel agency will provide a single point of contact for (1) air, rail, bus, lodging, and rent-a-car reservations; (2) the collection of cost, administrative, and travel data with provisions to generate detailed, multi-modal management reports; (3) the generation and delivery of mode tickets and hard-copy itineraries; (4) the increased use of transportation, lodging and rent-a-car discounts; and (5) toll-free twenty-four hour telephone access (40:10).

The government will reimburse the organization at cost of the services (tickets, lodging, and car rental) provided to the official traveller. All compensations must be collected in the form of commissions from carriers and others with whom travel accommodations are confirmed. If the installation commanding officer provides the necessary office space, the travel agency must locate its office on the installation. Should office space not be available on the installation, the travel agency is required to locate its office in a suitable facility within a ten-mile radius of the installation.

Test Objectives

The objective of the one-year pilot program test of the TMSP is to identify and evaluate potential economies, improved services, and problems associated with the use of a commercial organization to support official travel requirements (33:3).

The dollar savings and improved service to the DOD, associated with the TMSP, are expected in the following areas:

1. Production of detailed management reports useful for negotiating volume discounts for transportation, lodging, and rental cars.

2. Reduction of documentation and costs in processing documents.

3. Reduction in travellers' (and supporting staff) non-productive time.

4. Increased use of discounted fares and use of cost-favorable routings.

5. Increased use of discounted rental cars.

6. Increased use of discounted lodging (33:4).

The DOD requested contract proposals from all areas of the travel industry; i.e., the mode operators, carrier associations, travel agents, commercial vendors, and other interested transportation-oriented organizations, in order to select the travel agent most capable of fulfilling program objectives.

Test Site Selection

Test site selection is based on criteria which includes adequate dollar volume, diversity of travellers, favorable geographic location, and disbursing structure. Each service selected its own site: (1) Department of the Army--Tank Automotive Command, MI; (2) Department of the Navy--Marine Corps Development and Education Command, Quantico, VA; (3) Department of the Air Force--Travis AFB, CA.

Summary

A synopsis of the two travel management alternatives available to the DOD was presented in this chapter. A comparison of these alternatives (SATO as implemented at WPAFB and TMSP as implemented at Travis AFB) through subjective and quantitative analysis will be discussed in Chapter V. As mentioned earlier, Travis AFB does not have a SATO currently in operation. In order to make a valid comparison of SATO and TMSP performances, the authors selected a SATO location operating in a similar environment to Travis AFB. WPAFB SATO performance was chosen to be the comparative measure for the TMSP test performance at

Travis because it was the testing ground for the enhanced SATO concept. An in-depth discussion on the learning curve and the theory which the learning curve concept is based follows this chapter.

CHAPTER III

LITERATURE REVIEW

The United States' current economic plight coupled with the ever-increasing scrutinization of Department of Defense (DOD) spending by Congress, mandates an effective means of estimating and controlling travel costs. The July 1981 Hearing on Federal Travel Management before the Senate Committee on Governmental Affairs illustrated the national concern over efficient governmental spending on travel and all other facets of federal operations. This is true particularly in the DOD as defense spending increases. Senator William V. Roth, Chairman of the Governmental Affairs Committee, states in his opening remarks that, ". . . it is extremely important that as we increase defense expenditures, that the American public becomes persuaded that the money is well spent [50:6-7]." This sentiment is echoed by Deputy Secretary of Defense Frank Carlucci who states, "If DOD does not produce real savings and cost efficiencies, it will be hard to maintain the national consensus that now supports increased defense strength [56:28]."

Quantification of transportation costs and efficiencies has gained increasing importance due to the political environment in which the DOD operates. Committees such as the Senate Governmental Affairs Committee have demanded precise cost and travel data to evaluate the performance of federal management. Senator Roth summarizes this point as follows:

> We have heard for too long that no one knows how much federal travel goes on. Now we do [through the Interagency Travel Management Study] and the public is going to expect action [50:3].

Without precise cost and travel data to justify necessary travel programs, federal activities run the risk of being subjected to arbitrary budget reductions. For example, previous lack of travel data led to across-the-board travel cuts, some in excess of 500 million dollars a year (50:2-7).

This research presents a methodology based on learning curve theory by which future transportation economies affected by the Scheduled Airline Transportation Office (SATO) can be predicted. Operating largely on the basis of cost-volume relationships, learning curve theory has been used as a relatively accurate estimator of production costs. Learning curve theory particularly has been useful in the manufacturing and acquisition management environments. The purpose of this chapter is to examine learning curve theory and its applications.

Learning Curve Theory

Learning curve theory describes a phenomenon whereby an individual performing repetitive tasks achieves a more efficient production rate due to improved manual dexterity. Plotting unit or average unit production against time, the learning curve reveals a consistent relationship. As quantities of production double, time of production declines at a constant rate. This constant rate is referred to as the rate of learning. Rates of learning fall within a range of 50 to 100 percent, where a 50 percent learning curve infers that no additional time was required to produce the doubled quantity, and where 100 percent implies a total absence of learning (59:306). For example, if there exists a 90 percent rate of learning and the first production unit required forty hours of direct labor, the second unit would be produced in thirty-six hours and the fourth unit would be produced in 32.4 hours. Thus, it can be seen that the 90 percent rate of learning implies a 10 percent reduction in the time to produce the doubled unit of production.

While early psychological studies revealed the concept of learning as attributed to manual dexterity (37:6), the learning curve actually represents much more than aggregate labor learning effort. Learning also includes managerial innovations, engineering changes, and environmental improvements such as:

1. Improved tool coordination, shop organization and engineering liaison;

2. Improved subassembly design;

3. More efficient parts supply systems;

4. Utilization of more efficient tools; and

5. Utilization of quality materials (6:3; 5:89; 59:309).

In fact, some researchers attribute 90 percent of learning to management and engineering changes (19).

Lloyd outlines four major objectives of learning curve theory (26:222-223). Initially, the learning curve enables management to compare manufacturing performance records at different points in time. Through such comparisons, a company may establish corporate goals, standards of labor performance, marketing strategies, and planning initiatives. Secondly, it allows management to compare two or more plants producing the same or similar products. However, Baloff questions the validity of such comparisons as he refers to them as "questionable simplification(s)" and "subjective evaluation processes [7:249]." He contends that each plant, and even each process within an individual plant exhibits a unique pattern of learning. Hence, any subjective evaluation of the type proposed by Lloyd, Andress and others may not be sound. Thirdly, the learning curve is an absolute measure of efficiency. Finally, Lloyd cites the understanding gained from the evaluation of the learning curve itself as an objective. The identification of trends, and the search for the sources of efficiencies may be of greater value than the cost-estimating or cost-comparative capabilities of the curve.

There are a number of assumptions made when using learning curve theory. Among these are: (1) production statistics must be exposed to the effects of scale, learning, innovation, and competitive pressure; (2) the product must be uniform throughout production; (3) the learning curve may be considered only as one measure of industrial efficiency, and must be used in conjunction with other measures; and (4) all production costs must be expressed in real terms; e.g., 1972 dollars (21:50; 26:221).

As demonstrated in the first assumption, the learning curve describes more than the rate of learning. It also includes the scale of operation, managerial and technical innovation, and competitive pressures. As the capacity of the plant increases, opportunity for economies of scale also increases. Managerial and technical innovations, as discussed earlier, enhance production line capabilities as well as the work environment. Competitive pressures cause management to innovate, relay pressure to the work force, and seek constant production to take advantage of learning and to minimize breaks in production (15:7.15).

The third assumption describes the learning curve as a quantitative tool, a means of expression. The learning curve measures prod·ictivity in absolute terms. Quality of the product, the type of labor employed (skilled or semi-skilled), and other considerations often are not taken into account. Attempts to disaggregate the curve into labor, management and technical components have not been perfected (7:253). Therefore, the learning curve cannot stand alone as a measure of organizational efficiency.

The final assumption deals with the language of the learning curve, its data makeup. The data collected must be translated into real dollars to reach a level of equivalency through time by discounting inflation and other monetary phenomena (21:50).

The learning curve model is expressed mathematically as follows (12:605-606; 1:248):

$$Y_x = Kx^n$$

where,

x = unit number,

Y_x = number of direct labor hours to produce the xth unit,

K = number of direct labor hours required to produce the first unit,

n = slope parameter = log b/log 2, and

b = learning factor.

The mathematical expression given above is referred to as the "unit curve" or the "Boeing" theory (15:7.15). This formula provides an estimated cost for a specific unit. For example, the direct labor requirement for the fourth unit of production using a 90 percent rate of learning, when the first unit required 40 hours for completion, is calculated as follows:

$$Y_x = 40(4)^{\log .9/\log 2}$$
$$= 32.4 \text{ hours}$$

This formula thus provides an estimated cost, in dollars or time, for a specific unit and shows that the time or cost for any given unit is reduced exponentially as more units are produced.

The "cumulative average" or the "Northrup" version of the learning curve theory measures the cumulative average cost of a specific quantity of units (15:7.20). The Northrup formula is delineated below:

$$\bar{Y}_x = Kx^n$$

where,

x = unit number,

$\bar{Y}_x$ = the average number of direct labor hours to produce the xth unit,

K = number of direct labor hours required to produce the first unit,

n = slope parameter = log b/log 2, and

b = learning factor.

In the short run, there are advantages in using either of the learning curve approaches according to the degree of planning accomplished, and the level of risk involved. A high degree of planning, coupled with reduced risk, tends to favor the "Boeing" theory. The "Northrup" theory is preferred where risk tends to be greater, and the pressure of time has prevented a desired level of planning.

In the long run, however, the "Northrup" model tends to be asymptotic. That is, the "Northrup" model approaches the "Boeing" model on the curve to the point of being nearly identical with every point on the "Boeing" curve.

The learning curve may be displayed by two graphical means. Initially, when displayed on ordinary graph paper, the learning curve forms a hyperbolic figure. Secondly, on log-log paper, the learning curve becomes a linear function. Figure 3-1 graphically illustrates the arithmetic plot of the 90 percent learning curve example, and Figure 3-2 illustrates the customary logarithmic plot of the 90 percent learning curve. The second method of illustrating the learning curve is preferred due to the ease of making cost or labor hour estimates (15:7.16-7.17).

Learning Curve Applications

Numerous studies have been conducted concerning the application of learning curve theory to aircraft and other weapon systems production programs. The intent of these studies has been to expand the basic "Boeing" theory

```
Y = A*X↑B

A =
 40

B =
 -0.152003093445

R-SQUARE =
 1

RES ERROR
 4.658060824E-23

MAX(ABS(RESIDUAL))
 5.456968211E-12
```

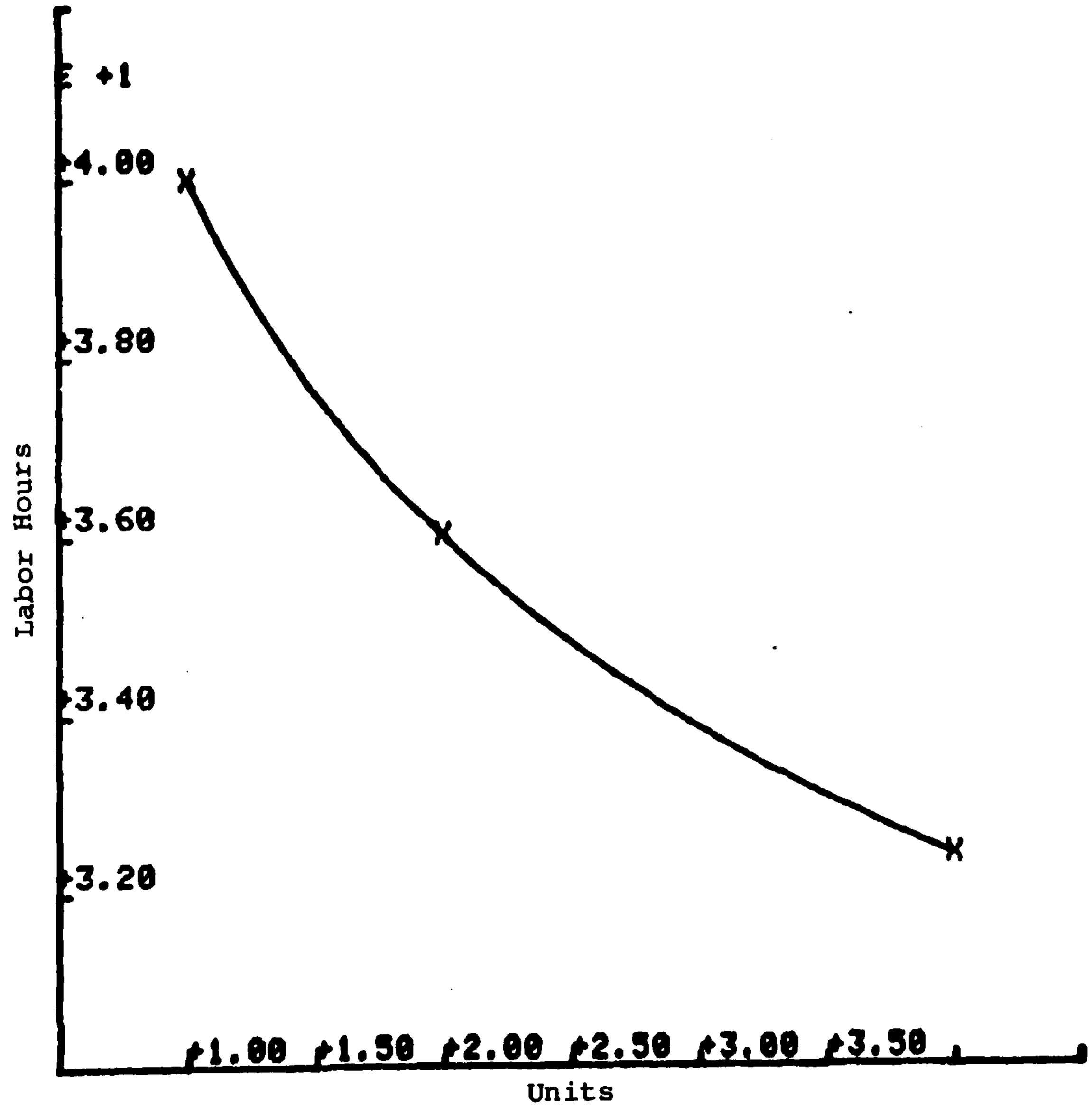

Fig. 3-1. Sample 90 Percent Learning Curve Plotted by the Plot 50 Simple Linear Regression Package

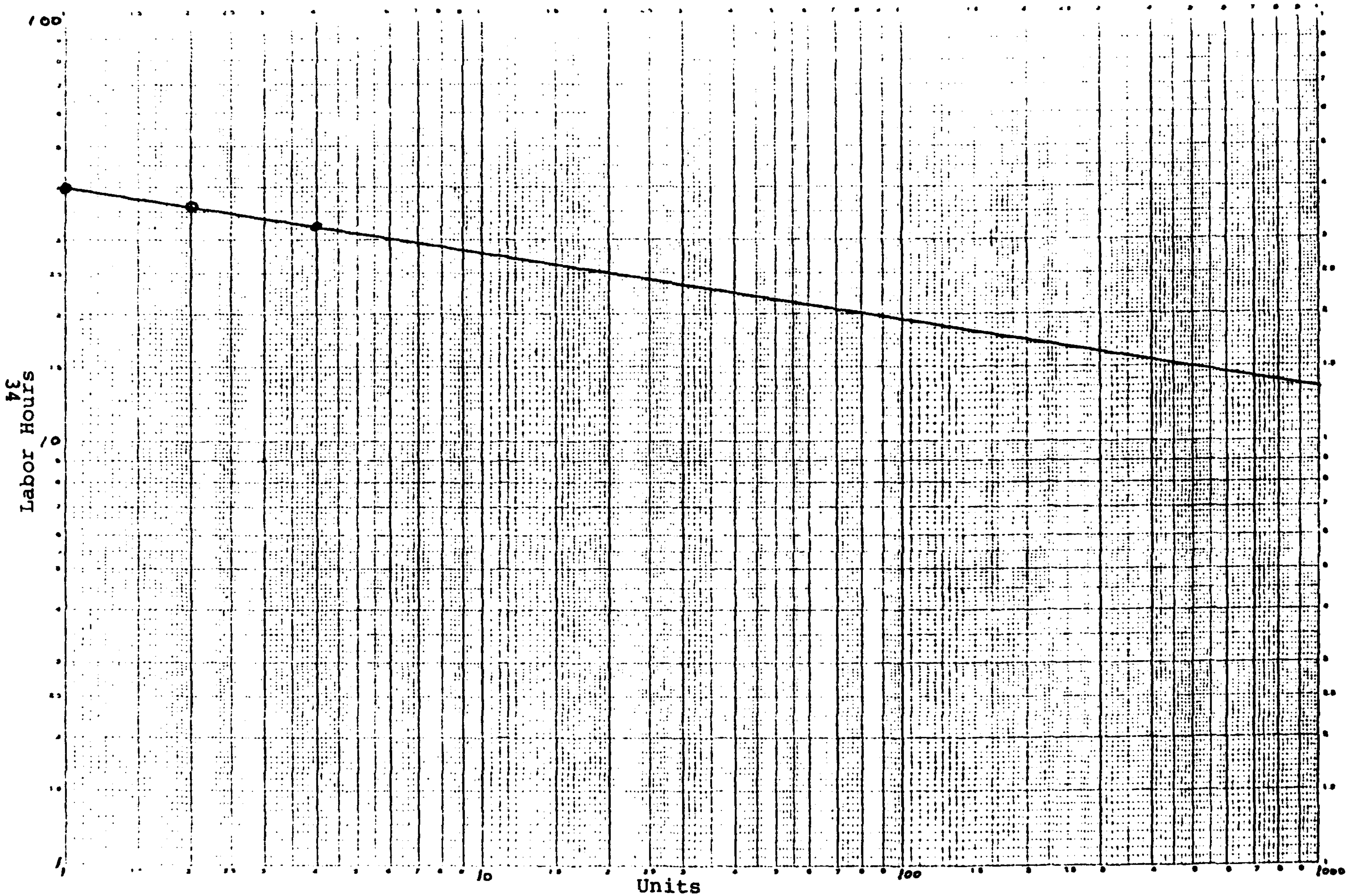

Fig. 3-2. Sample 90 Percent Learning Curve Plotted on Log-Log Paper

to explain more of the variation in program costs. The development of a generalizable formula to accurately predict weapon system costs of production has centered largely around Lieutenant Colonel Larry Smith's doctoral study. In this study, he demonstrates an inverse relationship between the production rate and labor requirements (45:139). This conflicts with prior studies conducted by Alchian and Allen, and Asher. The demonstration of this relationship built the foundation for Smith's study, and several others following his work.

Compiling direct labor hour statistics on the production of F-4, KC-135, and F-102 airframes, Smith formed sixteen data sets from which to test two major hypotheses. Initially, Smith sought to establish a goodness of fit in the data sets used to ensure applicability to learning curve concepts. He also omitted some of the most recent data points in each of the sets to test the predictive ability of his equation. Secondly, and most importantly, he tested his full model, the learning curve model plus a production rate variable, against what he labeled the "reduced" model, the unit learning curve equation (45:47). Smith found the following results:

1. The production rate variable contributed substantially to the explanation of the variance, or the mean square error.

2. The production rate variable improved the predictive ability of the learning curve model for the F-4 and F-102 aircraft programs. However, there seemed to be little improvement in the prediction of KC-135 costs through the use of Smith's full model (45:142-146).

Unfortunately, the follow-on research conducted using Smith's full model, while positive in their results, have not been conclusive. An analysis of these results will follow.

Crozier and McGann replicated Smith's research in the hopes of adding to a body of knowledge created by Smith and two other thesis efforts (13; 46). In their model, Crozier and McGann chose to study aircraft engine production, including the General Electric V-79, the Allison TF-41, and the Pratt and Whitney F-100 engines. The results of their study confirmed those of Smith's in three of six cases examined. In the study of the F-100 engine, the predictive ability of the full model was particularly strong (14:92-93). Crozier and McGann recommend the use of Smith's model throughout the life of the F-100 program. Nonetheless, they concluded that the use of the model depended heavily on the individual weapon system (14:94). A second major conclusion reached involved the realization that in extremely complex production programs, the learning curve tends to lose its effectiveness (14:93). This is contrary to one of the basic characteristics of the learning curve, its ability to assess complex systems costs (15:7.4-7.15).

A second major replication of the Smith model was conducted by Allen and Farr. In this case, Allen and Farr applied Smith's original two hypotheses to missile production. Results of the replication were mixed. While the predictive ability of the full model was high in the case of the SRAM missile, it was no higher than the unit learning curve model, the "reduced" model (3:100). The full model faired better in the Maverick data sets, demonstrating superior results in five of the eight data sets (3:100-101). Allen and Farr reached a conclusion similar to the thesis team preceding them. They concluded that "the superiority of the full model for prediction depends on the particular program and circumstance [3:101]."

While a great deal of effort has been expended in the quest for a generalizable learning curve formula, little attention has been devoted by military researchers to the problem of parameter estimation. Parameter estimation encompasses the determination of the initial unit production time, and the rate of learning. Researchers in the commercial sector "have [also] neglected this area for the last ten years [59:305-306]." There have been some solitary efforts, however. Baloff suggested a problem-solving group be used to establish initial productivity. He further suggests a relationship between the "a," the cost of producing the initial unit; and the "b," the rate of learning, parameters. He demonstrates an inverse relationship between the two as did Asher some two years before him (7:250-253). Baloff severely questions the use of subjective evaluation methods such as the use of past learning rate percentages, or those of similar plants or industries.

Parameter estimation problems have plagued the Air Force in major acquisition programs. A prime example is brought to light by the General Accounting Office (GAO) audit of a contract with the Lockheed Georgia Company. In this case, the United States Government paid Lockheed 32 million dollars over and above what the contract price for eight C-130 aircraft should have been (54:1). In this case, Lockheed Georgia provided the government Air Force Plant Representatives Office (AFPRO) with obsolete and false labor hour data. AFPRO personnel ignored the data and provided a recommendation to the Aerospace Systems Division based upon an unreported pricing method. The GAO study is convincing in its argument that the price paid, based upon a production lot of C-130s produced for the Philippine and Ecuadorian Air Forces, was high and inequitable. A previous lot of C-130s produced for the United States Air Force had cost considerably less, in large part due to a labor hour savings ranging from eleven to fourteen thousand hours per aircraft (54:2).

To be sure, the major problem confronting the United States Air Force in this case was the failure of AFPRO personnel to act on the false data provided. However, had an established rate of learning, and an initial unit production time been clear in the minds of AFPRO personnel, this exorbitant price may never have been paid. Similar problems have been encountered in the development of the B-1 bomber at the Strategic Systems Program Office. A rate of learning was agreed upon with the contractor; but neither party would agree on what constituted the initial aircraft produced. The contractor claimed it was the fourth aircraft produced, while the Air Force claimed it was the first aircraft assembled (19).

The final topic within the application section of this chapter entails a case study of a weapon systems contract with the Raytheon Company for the fourth lot of the EF-111A AN/ALQ-99E Tactical Jamming System. In the proposal provided by Raytheon, six learning curves were provided. Learning curves were provided for the transmitter, exciter and calibrator. Three additional learning curves were provided for the testing costs of each of these items (2:4-2 to 4-9). The contractor had projected a three to six month break in production over a total period of thirty-one months. The loss of learning associated with this break increased unit cost considerably.

In the negotiation of this contract, Lieutenant Mark Harland discovered several errors in the learning curves presented by the contractor (20). Harland also shortened the span of the contract from a proposed thirty-one months to twenty-six months. This allowed production to continue on a more constant basis. As planned, the production break was reduced to one and a half months (2:7).

Lt. Harland's knowledge of learning curve theory provided the Air Force with two major benefits. Nonetheless, it was not until the formulation of the Price Negotiation Memorandum that Harland realized the contractor had been overcompensated for loss of learning. The contractor was compensated for a 20.1 percent loss of learning during the production break (2:6). Using Andelohr's method to calculate loss of learning, Harland calculated a 9.872 percent figure (2:7).

Summary

The learning curve is a proven empirical tool in the production and manufacturing milieu. Used frequently in the defense acquisition system, the learning curve is a cost control and planning device. This research examines the flexibility of the learning curve. The applicability of the learning curve to service related industries, the base travel management organization in particular, is the primary focus of this study.

To close, Winifred B. Hirschmann presented four very simple, truthful statements succinctly summarizing learning curve theory.

1. Where there is life, there can be learning.
2. The more complex the life, the greater the rate of learning. . . .
3. The rate of learning can be sufficiently regular to be predictive. . . .
4. Learning is related to the dynamic context of the environment. . . . [23:138].

CHAPTER IV

METHODOLOGY

Introduction

This chapter focuses on the development of an approach to the basic research performed. The learning curve model is redefined in terms of the travel management environment. The variables within the model are described as being within or exterior to the system examined. Finally, a two-prong research question is developed to provide the direction for this study of learning curve theory in the travel management environment.

Objective

The objectives of this research are: (1) to determine the predictive ability of the learning curve in a travel management environment, and (2) to present a subjective analysis between the enhanced Scheduled Airline Traffic Office (SATO) and proposed Travel Management Services Program (TMSP).

Meeting these objectives will aid the Air Force in developing future performance goals for the SATOs, and provide the Air Force with a method of selecting a sound travel management program.

Approach

The approach to meet these objectives began with collecting the monthly percentages of passengers travelling under discount fares obtained from Continental United States (CONUS) Air Force bases which had implemented the enhanced SATO program. The sample size was limited to those SATO bases having at least fourteen months of operation under the enhancement concept, as of April 1982. Fourteen months of operation allowed for a twelve-month learning curve model development period, and a minimum of two months for model verification. The first twenty enhanced SATOs, shown in Table 4-1, met this criteria and, therefore, established the sample size of the data base.

The data base was subjected to a one-way Analysis of Variance (ANOVA), and a Duncan's Multiple Range Test to determine if the Wright-Patterson Air Force Base (WPAFB) SATO performance was generalizable to the population of the Air Force enhanced SATO bases; and therefore applicable as a comparative measure for expected performance, in terms of learning, at the Air Force TMSP test location (Travis AFB). The decision rule for these tests was to reject the null hypothesis if the test statistic (F-ratio) was greater than the critical statistic (F-critical) at the .05 significance level (27:638-639). The F-critical values were obtained from McClave and Benson's F-distribution tables (27:638-639).

TABLE 4-1

A LIST OF THE SAMPLE BASES

Barksdale	Lowry
Chanute	March
Charleston	Maxwell
Griffiss	McGuire
Hanscom	Offutt
Homestead	Patrick
Keesler	Scott
Kirtland	Sheppard
Lackland	Vandenberg
Los Angeles	Wright-Patterson

A histogram was then constructed using the aggregate data (all twenty bases combined) and WPAFB data to develop a null hypothesis for testing the distribution of the data. A residual analysis was done to determine if autocorrelation existed among the data points. The Kolmogorov-Smirnov (K-S) and Chi-Square tests were used to evaluate the following null (H_o) and alternative (H_a) hypotheses:

H_o: $f(x) \sim$ normal

H_a: $f(x) \sim$ not normal

The decision rule was to reject the null hypothesis if the test statistics were greater than the respective critical values. The critical values for the K-S test were extracted from L. H. Miller's "Tables of Percentage Points of Kolmogorov Statistics" (35:111-121). The Chi-Square values were taken from Benson and McClave's Critical Values of χ^2 Table (27:644-645).

The next step was to use a general learning curve analysis program called Learn Star (LEARN*), a packaged program available on the Copper Impact Computer system, to determine the rate of learning of WPAFB and all other enhanced Air Force SATOs based upon input data. The rates of discount usage were used as input to the 4051 Tektronix computer system to graphically depict the rates of learning. This system was also used to project a minimum of two performance points (March and April 1982) for the WPAFB and aggregate populations. These projected points were compared to the actual percentages of discount usage during these months to determine the range of the predictions.

The final step of this procedure was to forecast the expected performance of the Air Force and WPAFB over a twelve-month period. Projections were made assuming the number of passengers travelling during the forecast year will remain the same, be 10 percent higher and 10 percent lower than the data base year. This procedure provides data base year control units for the rates of discount fare usage. These projected performance levels may then be used to evaluate the performance data collected during the TMSP pilot test program.

Model Description

The model developed in this thesis is the basic unit curve model described in Chapter III. The unit learning curve was selected over the cumulative average curve due to the accuracy of prediction at each unit. Because the cumulative average curve is asymptotic, it is more accurate in a long-run scenario (15:7.23-7.24). The setting of this research is relatively short term as the authors examined sixteen months of data. Additionally, the use of the unit curve eliminates the "smoothing effect" of the cumulative average curve. The cumulative average curve may be deceiving as demonstrated in the following contrived example (19).

The government has been purchasing "flash hiders." The contractor furnished the following data and certified its accuracy.

Lot #	Lot Size	Cumulative Average Labor Hours
1	1	6500
2	1	4500
3	1	4833
4	1	3500
5	1	3300
6	1	3167
7	1	3071
8	1	3000
9	1	In process
10	1	In process
11	1	To be estimated
12	1	To be estimated

Estimating lots eleven and twelve by the cumulative average learning curve on log-log paper exhibits a relatively sharp rate of learning (see Figure 4-1). This cumulative average curve averages the total cost (labor hours) over the units produced. The unit curve, on the other hand, exhibits a straight line demonstrating the actual absence of learning in the production of "flash hiders." Thus, the unit curve provides a more accurate depiction of this cost volume relationship.

The unit curve model used in this research is based on the model developed by Chase and Aquilano. As described in Chapter III, the unit learning curve is expressed as

$$Y_x = Kx^n$$

where,

x = unit number,

Y_x = number of direct labor hours to produce the xth unit,

K = number of direct labor hours required to produce the first unit,

n = slope parameter = lob b/log 2, and

b = learning factor (12:605-606).

Model Translation

The learning curve model operationalized in this research redefined the basic unit model. The variable translations simply enabled the authors to apply learning

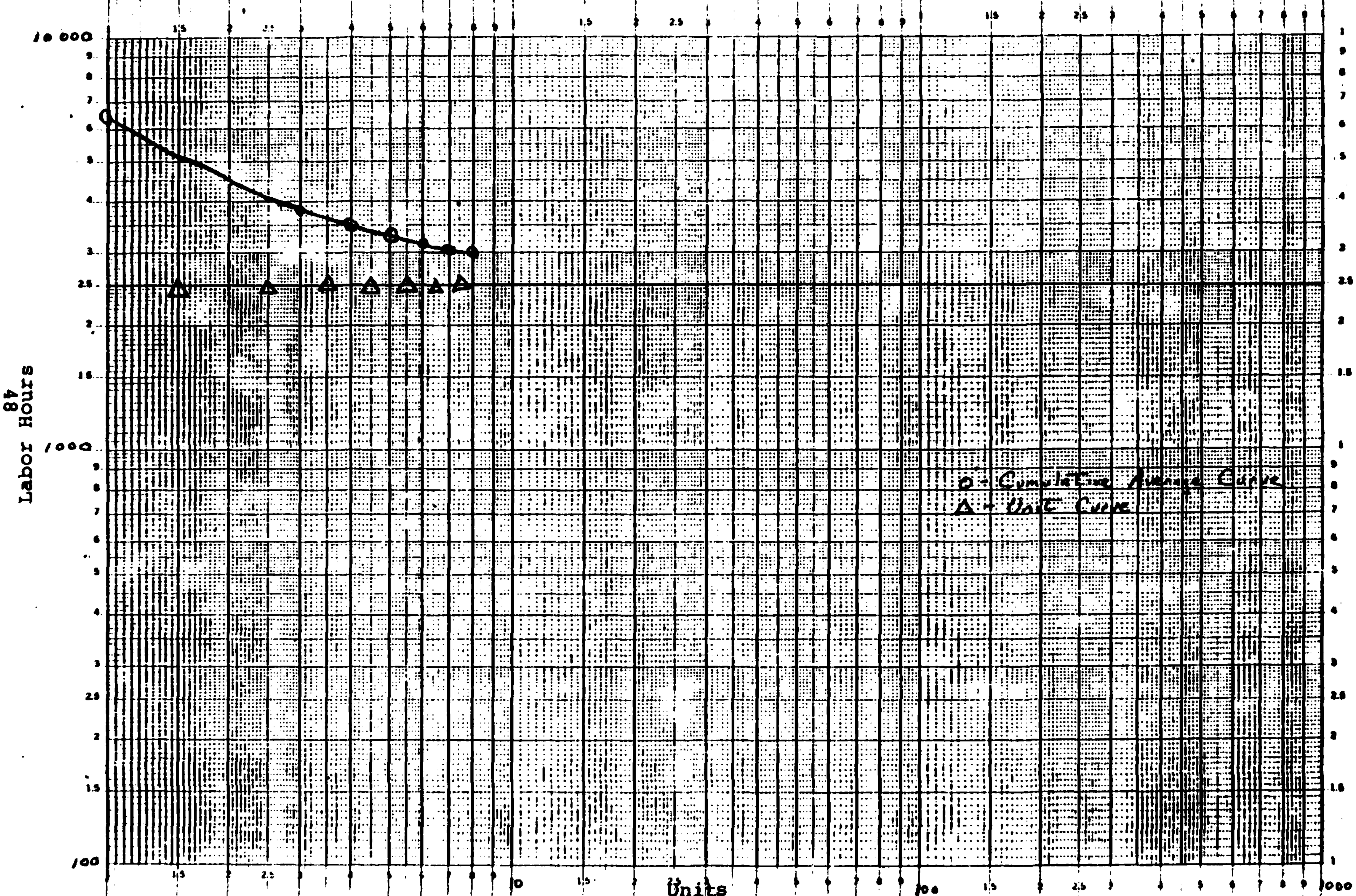

Fig. 4-1. A Comparative Graph of the Cumulative Average and Unit Learning Curves

curve theory to the Scheduled Airline Traffic Office environment. The applied model appears below:

$$Y_x = Kx^n$$

where,

- x = the number of passengers ticketed,
- Y_x = the rate of passengers failing to use airline discounts,
- K = the rate of passengers failing to use airline discounts as of the first ticketed passenger,
- n = slope parameter = $\log b/\log 2$, and
- b = learning factor.

Variables

The variables inherent to this applied model are the rate of passengers failing to use airline discounts, the number of passengers ticketed at the selected SATOs, the rate of discount usage as of the first unit produced (i.e., the first ticketed passenger), and the rate of learning. The purpose of this section is to define these variables as exogenous and endogenous, and to explain how the variables are used in the model. Shannon refers to exogenous or input variables as "variables originating or produced outside of the system or resulting from external causes [44:15]." He defines endogenous or output variables as "those [variables] produced within the system or resulting from external causes [44:14]." The discussion of the variable use, in the following subsections, is conducted largely in terms of learning curve theory.

Rate of Discount Usage

The rate of discount usage, or the failure of passengers to use discounts, is a function of the number of ticketed passengers and the number of discounts attained for those passengers. (Although referred to as the rate of discount usage, by a simple transformation this variable also represents the rate of failure to use discounts.) Hence, the rate of discount usage is an endogenous variable as it is an output of the SATO ticketing and reservation systems. The rate of discount usage, the left-hand side of the applied learning curve model, is dependent on the initial rate of discount usage, the unit produced, and the rate of learning. This variable is plotted along the vertical y-axis of the learning curve graph. The rate of discount usage is the primary output variable. This variable is treated as a major determinant of the success of a particular SATO enhancement program. The rate of discount usage is relative to the particular location as the number of passengers and the discounts available heavily influence the total dollar savings.

Number of Passengers

The number of passengers travelling from each SATO location is outside the realm of the ticketing and reservation system. The number of passengers is an input or exogenous variable because the magnitude of this variable is determined by the installation travel mission (47). This variable is of particular concern to SATO management as its manpower planning and funding are based on monthly installation passenger traffic figures (47). In the applied model, the number of passengers is plotted along the horizontal x-axis of the learning curve graph. The number of passengers ticketed aids the determination of the rate of discount usage in relation to the specified rate of learning. Although the number of passengers is a given value in the equation provided earlier in this chapter, it is a crucial variable in developing the unit curve plot points.

Rate of Discount Usage/ First Unit

The rate of discount usage required to produce the initial unit (i.e., process the first passengers) is an exogenous variable. That is, it is input into the proposed model after determining its value through an assessment of the learning curve slope, and the use of known discount usage and passenger unit values. The variable is an output of its determining model, and an input into the learning curve model where the dependent variable is the rate of discount usage.

Rate of Learning

The rate of learning may be determined graphically, through learning curve equations, or through prepared computer routines. Through any one of these processes the rate of learning may be considered as an output variable. However, throughout this research the rate of discount usage remains as the focused variable. As a result, the rate of learning and the resultant learning factor computed by log b/log 2 are exogenous variables.

Summary

The subjective distinction of variables as inputs or outputs establishes the boundaries of the proposed system or model. The system described through the above variables demonstrates the multirole nature of system variables. Variables are both inputs and outputs, their nature dependent on the stage and design of the system (42:14-19). Figure 4-2 illustrates the multirole nature of the three exogenous variables (number of passengers, rate of discount usage/first unit, and rate of learning). The endogenous variable is a result of several factors over two phases of mathematical operations.

Research Question

The research question posits two major queries in this study. The initial query investigates the learning curve's utility as an accurate predictor of the rate

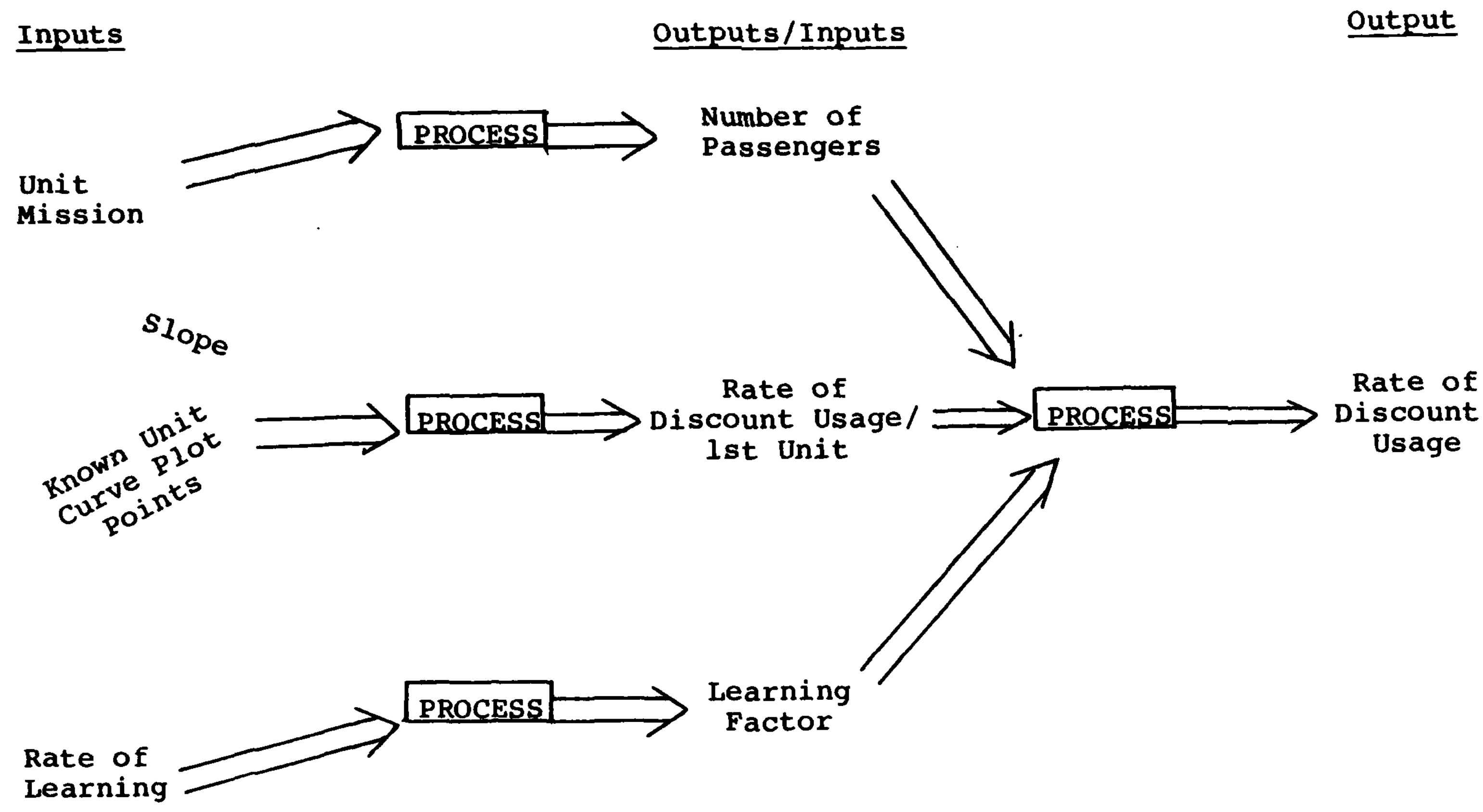

Fig. 4-2. The Multirole Nature of System Variables

of discount fare usage. The second part of the question examines learning curve theory as a means for establishing air transportation cost criteria. The first query is demonstrated in this study. The second query may be examined upon completion of the Travel Management Services Program (TMSP) test at Travis AFB, California. While proposed criteria are provided in this study, they are untestable as the TMSP test has confronted several legal delays due to contractual problems.

Research Question, Part One

The learning curve's use as an accurate predictor of the rate of discount fare usage provides the major test of this research. Developing learning curves based on the first twelve months of operations at the first twenty SATO locations, the authors predict discount fare usage at the twenty SATO locations and in aggregate form. The first months of operation vary from January to March 1981 due to the phased implementation of the enhanced SATO program. Consequently, actual data available for each SATO location varies by when the enhanced SATO concept was implemented. After the development of the learning curves, the authors will examine the deviation of the predicted discount fare usage from the actual discount fare usage. Based on this deviation, the authors will make an assessment of learning curve utility in the airline ticketing and reservations environment.

Research Question, Part Two

The second research query proposes the use of the learning curve theory as a means of establishing transportation cost criteria. By establishing a table of discount fare usage rates, the TMSP test data may be compared to the SATO performance data. In other words, the criteria developed would provide a benchmark model for easy comparison to other proposed travel management systems. The ability of the learning curve to project prediction values normally describing system phenomena (actual discount fare usage) in part would demonstrate the value of the learning curve as a control mechanism.

Summary

This chapter provided the approach to the basic research in this thesis. A description and translation of the model, the explanation of the individual variables, and the statistical approach to this research provide the foundation for the next two chapters. The data analysis and the evaluation of the two-part research question follows in Chapter V. The authors' conclusions and recommendations for further research are presented in Chapter VI.

CHAPTER V

DATA ANALYSIS AND RESULTS

Introduction

In this chapter, the authors examine the monthly SATO (Scheduled Airline Traffic Office) data collected by the Air Transport Association for the Air Force Transportation Directorate. A statistical analysis of the data attempts to identify the SATO located at Wright-Patterson AFB (WPAFB) as a reflection of the aggregate Air Force SATO population. The authors also provide an examination of the aggregate SATO performance data to analyze the total Air Force SATO picture. The second major focus of this chapter is an analysis of learning curve projections regarding monthly rates of discount usage. Mean Absolute Deviations (MADs) and tracking signals are calculated to determine the relative accuracy of the learning curves employed. Finally, the authors provide a subjective analysis of the SATO and Travel Management Services Programs (TMSP) based on the most current literature available.

Data Analysis

The application of learning curve theory requires a steady improvement in the number of discounted fares during the first twelve months of operation. A histogram was constructed with the aggregate data and statistical ANOVA and Duncan's Range Tests were performed to analyze the aggregate and Wright-Patterson AFB (WPAFB) SATOs' performance.

As stated in Chapter IV, the data base consisted of the monthly percentages of discounted fares provided to the official traveller at the first twenty Air Force enhanced SATO bases. The Office of the Director of Transportation (HQ USAF/LETT) provided the collected data, January 1981 through April 1982, to the authors.

The raw data was entered into a data file (month by base by percent of discounted fares) on the Control Data Corporation computer system for analysis (see Appendix C for raw data). Next, the one-way Analysis of Variance (ANOVA) and Duncan's Multiple Range Test were performed to determine if Wright-Patterson AFB (WPAFB) SATO performance was generalizable to the Air Force population of enhanced SATO bases. The hypothesis of the ANOVA test was:

$$H_o\text{:}\ \ \mu_1 = \mu_2 = \mu_3 = \cdots \mu_{20}$$
$$H_a\text{:}\ \ \text{At least one } \mu_i \text{ is different}$$

The results of the ANOVA test shown in Table 5-1 led to a rejection based on the decision rule described in Chapter IV: reject H_o if the test statistic, F-ratio, was greater

TABLE 5-1

ANALYSIS OF VARIANCE PERCENTAGE OF DISCOUNTS BY BASE

F-ratio	16.178
Significance Level	.000
F-Critical (n=20, K=2, N-(K+1))	3.590
Alpha Value	.050

Note: Rejection region: F-ratio > F-critical.

than the critical statistic, F-critical at a .05 significance level.

These results identified a difference in mean performance levels in terms of providing discount fares to the traveller among the sample bases. This statistical analysis was confirmed by the observations of Mr. Michael Thompson, Manager of the WPAFB SATO, who stated, "Due to the uniqueness of each base, it is impossible to compare the percentage of discounts given across the bases [47]." The percentage of discounts given is a function of many variables which are not controllable by an installation's SATO. The variables include local airline market, level of competition, base unit mission requirements and distance travelled.

The Duncan's Range Test was performed to observe which bases had different means and if the WPAFB mean was similar to enough bases to justify a generalization of

WPAFB performance to the population of the Air Force's enhanced SATOs. The criteria set for the generalization of WPAFB mean performance was for the WPAFB mean to appear in the same population of at least 51 percent of the sample bases means. The Duncan's Test revealed that the WPAFB mean percent of discounted fares (41.2 percent) was significantly different from fifteen of the nineteen bases analyzed. This equates to a 26 percent generalization. The WPAFB SATO performance failed to meet the set criteria; therefore, WPAFB SATO performance could not be generalized to represent the aggregate sampled enhanced SATO bases. The uniqueness of the sample bases was borne out in the Duncan Test where the twenty means, which varied from 32.1 percent to 93.2 percent, were paired to ten homogeneous subsets.

Based on these findings, a subjective analysis in terms of the variables mentioned above rather than a statistical analysis, was needed to determine a base whose historical data was appropriate for use in developing the comparative measure for the TMSP pilot test data.

After subjectively analyzing the data base, the authors concluded that McGuire Air Force Base, New Jersey, displayed a strong case as a suitable comparative measure for the TMSP pilot test.

The type and level of airline competition at these airports are assumed to be parallel. McGuire AFB and

Travis AFB have operational characteristics in common. A numbered Air Force headquarters is located at each base. Twenty-first Air Force HQ is at McGuire while Twenty-second Air Force HQ is at Travis. Both bases belong to the Military Airlift Command (MAC) which operates a fleet of C-5 and C-141 aircraft and commercial contracted aircraft for transporting cargo and military members and their families to and from the CONUS. These characteristics describe a large portion of McGuire and Travis mission requirements which direct the traffic flow requiring SATO and/or TMSP services.

Learning curve theory describes a phenomenon whereby an individual performing repetitive tasks achieves a more efficient production rate due to improved manual dexterity and managerial and engineering improvements. In order to have applied the learning curve to this industry, some rate of learning over time had to be shown. This analysis was performed on the aggregate data since the hypothesis that WPAFB SATO performance is generalizable to the aggregate performance was rejected.

Data Distribution

The aggregate distribution analysis began with the construction of a histogram that is shown in Figure 5-1. The graph shows 240 data points categorized into eight classes. The relative frequency of these classes depicts

```
CODE
  I
1. **** (    6)
  I
  I
2. **** (    6)
  I
  I
3. ************ (    22)
  I
  I
4. ********************* (    40)
  I
  I
5. ******************** (    38)
  I
  I
6. ********************** (    44)
  I
  I
7. **************************** (    54)
  I
  I
8. **************** (    30)
  I
  I
  I.........I.........I.........I.........I.........I
  0        20        40        60        80       100
  FREQUENCY
```

MEAN	5.483	STD ERR	.114	MEDIAN	5.682
MODE	7.000	ST DEV	1.774	VARIANCE	3.146
KURTOSIS	-.510	SKEWNESS	-.449	RANGE	7.000
MINIMUM	1.000	MAXIMUM	8.000	SUM	1316.000
DEV. PCT	32.348	.95 C.I.	5.258	TO	5.709

VALID CASES 240 MISSING CASES 0

Fig. 5-1. Histogram of Data Base

Notes:

Histograms were constructed with 10, 13, and 20 classes also. The shape remained the same.

A histogram or ANOVA analysis was not performed on McGuire individually. The twelve data points available at this writing were not sufficient for conclusive results.

a distribution skewed to the left. The condescriptive statistics of the aggregate data included a median greater than the mean, therefore leftward skewness was expected. The histogram of the aggregate data suggested a possible growth rate in the performance levels. An ANOVA test was performed on the data comparing the twelve months of operation to evaluate what appears to be growth in the number of discounts given. The hypothesis tested was

H_o: $\mu_1 = \mu_2 = \mu_3 = \dots \mu_{12}$

H_a: At least one month's mean was different

A rejection of H_o was accepted based on the decision rule and the ANOVA test results which are listed in Table 5-2.

TABLE 5-2

ANALYSIS OF VARIANCE PERCENTAGE OF DISCOUNTS BY MONTH

F-Ratio	7.601
Significance Level	.000
F-Critical (n=12, K=2)	4.260
Alpha Value	.050

Note: Rejection region: F-ratio > F-critical.

A Duncan's Range Test was performed to identify any significant differences between the monthly SATO performances. The monthly means increased from 40.9

percent discounted fares in January to 62.9 percent in June to 75.5 percent in December. The Duncan's analysis concluded a difference between the early months of operation versus the latter months performance (see Table 5-3). As with any time series data, autocorrelation or interdependence between the parameters was expected. The data must represent this attribute, above all others, for proper learning curve application. Therefore, a regression analysis was performed to test for the presence of autocorrelation. A F-ratio of 77.028 at .000 level of significance was more than substantial evidence there exists some degree of autocorrelation among the twelve months performance levels (see Table 5-4).

Summary

The data analysis was performed to show the applicability/nonapplicability of the learning curve to data generated from a travel management industry. The ANOVA and Duncan's Range Test showed there was a difference among the monthly performances and the difference among the means were due to a growth rate during the twelve months under study. The presence of autocorrelation suggests a performance in a given month, T, is dependent upon the performance in month T-1. Based upon these facts, applying the learning curve to this set of data was deemed

TABLE 5-3

SUBSET GROUPINGS OF THE SAMPLE MONTHS' MEANS

Subset 1

GROUP	GRP 1	GRP 2	GRP 3
MEAN	40.9230	45.0800	50.8350

SUBSET 2

GROUP	GRP 2	GRP 3	GRP 4
MEAN	45.8000	50.8350	55.2600

SUBSET 3

GROUP	GRP 3	GRP 4	GRP 5	GRP 6
MEAN	50.8350	55.2600	59.6500	62.9150

SUBSET 4

GROUP	GRP 4	GRP 5	GRP 6	GRP 7
MEAN	55.2600	59.6500	62.9150	67.8750

SUBSET 5

GROUP	GRP 5	GRP 6	GRP 7	GRP 8	GRP 10	GRP 9
MEAN	59.6500	62.9150	67.8750	71.0250	72.1800	72.7550
GROUP	GRP 11					
MEAN	73.1600					

SUBSET 6

GROUP	GRP 6	GRP 7	GRP 8	GRP 10	GRP 9	GRP 11
MEAN	62.9150	67.8750	71.0250	72.1800	72.7550	73.1600
GROUP	GRP 12					
MEAN	75.4900					

TABLE 5-4

REGRESSION ANALYSIS TESTING FOR AUTOCORRELATION

F-Ratio	77.028
Significance Level	.000
F-Critical (n-240, K=2)	3.000
Alpha Value	.050

Note: Rejection region: F-ratio > F-critical.

valid, and the process of forecasting FY83 SATO performance for the aggregate and McGuire commenced.

Research Question

The dichotomous research question, described in Chapter IV, examines the use of learning curve theory in predicting air transportation discount usage at twenty Air Force Scheduled Airline Traffic Office (SATO) locations and in aggregate form. It further examines the use of learning curve theory in establishing cost criteria from which an alternative to the SATO program may be considered. This part of the research question currently is untestable, however, as the Travel Management Service Program test awaits its inception at Travis AFB, California.

Analysis of Research Question--Part One

The initial part of the stated research question examined the ability of the learning curve to predict airline discount usage at the twenty original SATO locations and in their aggregate form. An examination of learning curve utility in this area follows through a presentation of the data and the learning curve plots, the calculation of learning curve slopes, the comparison of actual discount fare usage to the predicted rates of usage, and the calculation of the mean absolute deviations (MADs) for the selection of a learning curve model and tracking signals for the establishment of fare usage control limits.

Learning Curve Data
and Graphs

The data for each of the twenty original bases and their aggregate are provided in Appendix C. The data is arranged according to the month of SATO operation. The numbered month represents the first through the twelfth month of operation. The first month represents January, February, or March 1981, dependent on the SATO selected. The data depicts the number of passengers ticketed at the SATO in unit (column 2) and cumulative (column 4) forms. The number of passengers travelling with a discounted fare is provided in column 3. The percentage of passengers travelling with a discount is obtained by dividing the number of passengers travelling under a discounted fare by the total number of passengers ticketed. An algebraic midpoint, and the plot points x and y are provided based on a heuristic routine shown in Table 5-5 (19).

The authors found consistent growth in the discount usage rates when the computed discount usage figures were examined. With the possible exception of Maxwell AFB, Alabama, each of the bases, and their aggregate, made steady gains in discount usage from month to month. This growth is better illustrated by learning curve graphs. Two forms of learning curves are provided in Appendices D and E. Appendix D illustrates the learning curves plotted on log-log paper providing a straight line fit to the plotted points. Appendix E provides learning curve graphs performed by Volume I of the 4051 Tektronix Simple Linear Regression package. These graphs are hyperbolic in nature. The authors observed growth in each of the graphs of the twenty SATO locations and their aggregate. The extent of this growth is evaluated in the following section.

Rate of Learning

Rates of learning were calculated in three different manners. Initially, the authors calculated the learning curve slope by using the Learn* program, a prepared program available on the Copper Impact computer system. The instructions for the use of this program are available

TABLE 5-5

HEURISTIC ROUTINE

Step One:	Set cumulative units (CU) equal to zero above month one.
Step Two(A):	If this is the first month's data, determine if the number of passengers ticketed is greater than nine. If the answer to the former question is negative, refer to step two(B). Otherwise, continue following the routine through this step. If the answer to the latter question is affirmative, divide the number of passengers ticketed by three. If negative, divide the number of passengers ticketed by two. The resultant figure represents the initial month's midpoint. Continue on to step three.
Step Two(B):	Divide the following month's number of ticketed passengers by two.
Step Three:	Find plot point x (PPx) by adding the month midpoint to the previous month's cumulative unit total (CU_{I-1}).
Step Four:	Find plot point y (PPy) by subtracting the rate of discount fare usage (the number of passengers ticketed, multiplied by 100) from 100. (Normally, PPy remains as the lot value, the number of passengers with discounts, divided by the lot size, the total number of passengers. In this case, PPy is subtracted by 100 to better illustrate the improvement in the discount usage rates.)
Step Five:	Total the cumulative units (CU) by adding CU_{I-1} to the number of ticketed passengers for the current month.
Step Six:	If another month of data exists, return to step two(B). If the monthly data has been exhausted, the routine is complete.

in Table 5-6. A second method of slope calculation was performed graphically on log-log paper. A slope was obtained by measuring the rate of change in doubled x value units, and comparing that rate of change against unity on the y-axis. The third, and final, method for measuring the rate of learning involved using the B exponent calculated for each base and the aggregate by the 4051 Tektronix Simple Linear Regression Plot 50 package. The B exponent represents log b/log 2 in the equation $Y = AX^B$. By transforming the basic equation, the rate of learning = $2^B \times 100$. The authors used this transformed equation to determine a third learning curve slope for the twenty-one learning curves. The results of these three methods are provided in Table 5-7. The slopes in Table 5-7 are calculated based on the rate of discount usage by unit. Appendix F gives the slopes calculated on the basis of discount usage by month through the Plot 50 package.

The learning curve slopes measured by each of the above methods demonstrate a wide range of variability between the SATO locations. In the Learn* program, the rates of learning exhibit a range of 80.25 percent at Chanute AFB, Illinois, to 98.44 percent at Maxwell AFB, Alabama. Learn* measured the aggregate rate of learning at 91.47 percent.

TABLE 5-6

GENERAL LEARNING CURVE ANALYSIS PROGRAM

TYPE OF ANALYSIS (JOB) DESIRED?

1 - CALCULATION OF FIRST UNIT VALUE, SLOPE, AND EXPONENT OF LEARNING CURVE FROM UNIT OR LOT DATA. OPTIONAL DETAILS AND GRAPH.

2 - CALCULATION OF UNIT, CUMULATIVE TOTAL, AND CUMULATIVE AVERAGE VALUES GIVEN FIRST UNIT VALUE, SLOPE, AND UNIT NUMBER.

3 - CALCULATION OF LOT TOTAL AND AVERAGE UNIT VALUE FOR LOT GIVEN FIRST UNIT VALUE, SLOPE, AND INCLUSIVE UNIT NUMBERS.

4 - CALCULATION OF LOT TOTAL AND AVERAGE UNIT VALUE FOR LOT WITH A CHANGE GIVEN FIRST UNIT VALUE, SLOPE, INCLUSIVE UNIT NUMBERS, PERCENT WORK DELETED, PERCENT WORK ADDED, AND THE UNIT NUMBER AT WHICH THE CHANGE IS EFFECTIVE.

5 - CALCULATION OF FIRST UNIT VALUE, GIVEN UNIT NUMBER, VALUE AT THAT UNIT, AND SLOPE.

6 - STOP PROGRAM EXECUTION.

JOB?

TABLE 5-7

LEARNING CURVE SLOPES

Base	Learn*	Plotted Slope	Plot 50
Barksdale	94.11	80	89.82
Chanute	80.25	66	63.50
Charleston	90.99	80	86.92
Griffiss	91.71	83	85.98
Hanscom	83.82	74	72.51
Homestead	96.49	88	92.59
Keesler	91.00	79	84.60
Kirtland	84.61	71	74.54
Lackland	84.28	78	74.71
Los Angeles	81.62	64	70.25
Lowry	89.39	76	82.29
March	81.34	70	70.03
Maxwell	98.44	96	97.45
McGuire	85.21	70	77.61
Offutt	94.41	92	91.38
Patrick	82.41	76	71.55
Scott	93.88	85	89.27
Sheppard	91.10	78	84.87
Vandenberg	87.51	70	79.64
Wright-Patterson	94.74	84	90.60
Aggregate	91.47	72	85.66

The graphically derived rates of learning provided a range of 66 percent at Chanute AFB to 96 percent at Maxwell AFB. This method provided a rate of learning for the aggregate of 72 percent.

The final method of calculating the learning curve slope, through the 4051 Tektronix system, provided a range of slopes from 63.50 percent at Chanute AFB, to 97.45 percent at Maxwell AFB. The aggregate rate of learning slope was measured as 85.66 percent.

There also is wide variability between methods of slope calculation. This especially is true between the Learn* and 4051 Tektronix programs. This variance is evidenced in some of the following examples where the Learn* percentage is followed by the Tektronix percentage:

Chanute	80.25/63.50
Hanscom	83.82/72.51
Keesler	91.00/84.60
Los Angeles	81.62/70.25
Patrick	82.41/71.55
Aggregate	91.47/85.66

The variability between each of the three methods is common in other applications. For example, in contract negotiation in the Air Force acquisition process, the contractor and the government agree upon a selected computer program to determine rates of learning and subsequent unit costs (19). This agreement is made because it is recognized that the variability existent between programs would make negotiations difficult when both parties use different programs. Similarly, a choice of a particular method of slope determination was necessary in this research. The slopes determined graphically and the slopes determined by the transformed equation, the rate of learning = 2^B x 100, exhibited relatively similar results. The slopes determined for Chanute AFB, Illinois (66 percent/63.50 percent), Griffiss AFB, Indiana (83 percent/85.98 percent), Hanscom AFB, Massachusetts (74 percent/72.51 percent), March AFB, California (70 percent/ 70.03 percent) and Offutt AFB, Nebraska (92 percent/91.38 percent) demonstrate the similar results obtained by the two methods. As a result, the authors chose the 4051 Tektronix method of calculating the slope and projecting future discount usage rates for its advantages of automation, user friendliness, and relative accuracy.

Prediction of the Discount Usage Rates

The authors predicted the discount usage rates for a maximum of two months per SATO location based on the initial twelve months of data. Projections were obtained through the use of the 4051 Tektronix computer system. Projections for each location were made based on three different regression models. The first model was the learning curve unit model where the rate of failure to use discounts was plotted against the numbered month. The second model was a unit learning curve model where the rate of failure to use discounts was plotted against the units produced. In this model, the authors assumed the number of passengers ticketed for the predicted month remained the same as the calendar month of the previous year. The third regression equation used depended on a best fit analysis performed by the Plot 50 Simple Linear Regression package. Table 5-8 provides the equations available by this package to best fit the initial twelve months of data. The best fit is a result of regression analysis which examines the residual error of the twelve data points from the lines constructed by eight different equations. The line possessing the least maximum absolute residual error (the distance from the data point to the least squares line) was chosen as the best fit equation. Table 5-9 matches the twenty SATO locations and their aggregate with their best fit equations. Appendix G provides the best fit results by the eight available equations for each of the twenty SATO locations and their aggregate. Examining the best fit equations, the authors found the unit learning curve to provide the best fit in only two of the twenty-one populations. Specifically, Patrick and Wright-Patterson AFBs were the only two SATO locations having the least maximum absolute residual error

TABLE 5-8

REGRESSION EQUATIONS AVAILABLE FROM THE PLOT 50
SIMPLE LINEAR REGRESSION PACKAGE

$$Y = AX$$

$$Y = A+BX$$

$$Y = A(EXP)^{BX}$$

$$Y = \frac{1}{(A+BX)}$$

$$Y = A+B/X$$

$$Y = A+B(LOG(X))$$

$$Y = AX^{B}$$

$$Y = \frac{X}{(A+BX)}$$

TABLE 5-9

BEST FIT EQUATIONS FOR THE TWENTY SATO LOCATIONS AND THEIR AGGREGATE

Barksdale	$Y = A+BX$
Chanute	$Y = A+BX$
Charleston	$Y = A+BX$
Griffiss	$Y = A+BX$
Hanscom	$Y = A(EXP)^{BX}$
Homestead	$Y = A+B(LOG(X))$
Keesler	$Y = 1/(A+BX)$
Kirtland	$Y = A+BX$
Lackland	$Y = A+BX$
Los Angeles	$Y = A(EXP)^{BX}$
Lowry	$Y = A(EXP)^{BX}$
March	$Y = A+BX$
Maxwell	$Y = 1/(A+BX)$
McGuire	$Y = A+BX$
Offutt	$Y = A+B/X$
Patrick	$Y = AX^{B}$
Scott	$Y = A+BX$
Sheppard	$Y = A(EXP)^{BX}$
Vandenberg	$Y = A(EXP)^{BX}$
Wright-Patterson	$Y = AX^{B}$
Aggregate	$Y = 1/(A+BX)$

when modeled by the unit learning curve. This finding will be addressed in the final chapter of the thesis.

<u>Comparison of Actual to Predicted Values</u>

To compare the predicted rates of failure to use discounts to the actual rates of discount fare nonusage, the authors used the mean absolute deviation (MAD) as a device for judging the magnitude of the deviation and selecting the best regression model. The MAD is calculated by summing the absolute deviation between the actual and forecasted values and dividing that sum by the number of months forecasted (12:88). The calculation of the MADs for each of the three models is provided in Appendix H. Table 5-10 displays the MAD values according to SATO location and by regression model. The unit learning curve plotted by discount usage rate and month consistently predicted the discount usage rates better than the learning curve plotted by discount usage rate and unit, and the best fit models. Specifically, in thirteen of the twenty-one populations, the learning curve plotted by month provided the most accurate results. In contrast, the learning curve plotted by unit provided the most accurate results in only four of the twenty-one cases. This model may have been limited in its effectiveness due to the assumption of a constant demand from the previous year's passenger traffic. Additionally, a change in the

TABLE 5-10

MEAN ABSOLUTE DEVIATIONS

SATO Location	Learning Curve by Month	Learning Curve by Unit*	Best Fit
Barksdale	7.1	7.7	4.5
Chanute	7.2	7.2	1.4
Charleston	8.6	9.3	11.3
Griffiss	12.7+	15.4+	2.5+
Hanscom	6.2	7.1	6.9
Homestead	3.8	3.9	3.9
Keesler	4.0	4.0	4.5
Kirtland	2.6	3.5	2.9
Lackland	.7	.7	3.8
Los Angeles	1.7	2.2	5.5
Lowry	3.8	5.2	1.4
March	4.7	3.1	15.5
Maxwell	14.9+	15.9+	13.0+
McGuire	6.7+	11.8+	11.4+
Offutt	4.5	4.9	7.0
Patrick	7.3	6.2	7.3
Scott	2.3	3.2	8.7
Sheppard	3.6	6.4	3.5
Vandenberg	4.9	5.4	8.4
Wright-Patterson	4.1	7.6	6.1
Aggregate	1.0	3.4	1.3

Notes:

*Assumes the number of passengers in the travel month to be the same as the identical month of the previous year.

+Discounting the change in the reporting system as of 1 March 82, the MADs for Griffiss would have been 22.6, 19.9, and 37.8, and for the Maxwell SATO they would have been 16.6, 15.9, and 18.5, respectively. The data classified under partial discount codes was incorporated into Maxwell, Griffiss and McGuire AFBs as their deviation under the provided data was too great to be realistic. Confusion in the field regarding the proper reporting of partial discounts was confirmed to cause aberrations in the data (16; 10; 18). The double-digit partial discount codes were incorporated into Maxwell, Griffiss and McGuire AFBs to provide more realistic data. This matter is discussed further in Chapter VI of this study.

SATO/Air Transport Association (ATA) reporting system changed the value of the number of discounts offered in March, 1982 (47; 16; 11; 18). The change in the definition of a discount caused a change in the reported number of discounts used. As a result, the learning curve plotted by unit predicted the discount usage values best in only two of the twenty-one populations, Griffiss and Maxwell AFBs. Finally, the best fit models, while they minimized the maximum residual error in the initial twelve months data, did not perform well as predictors for the actual rates of discount usage. These models accurately predicted the actual values of discount usage in only six of the twenty-one cases. As explained earlier, without a change to the definition of a discount, the best fit models would have been accurate in only four of the twenty-one cases.

In terms of magnitude, the MADs displayed relative success in the use of the unit learning curve plotted by month. When using a criterion of MADs less than or equal to five, the unit learning curve was successful in thirteen out of twenty-one cases. In other words, the predicted rate of discount usage for thirteen of the twenty locations and their aggregate fell within a MAD value of five when compared to actual values. Broadening the criterion to MAD values of ten, encompassed all but two of the calculated MADs.

Tracking signals were calculated to determine the direction of the predictions, whether they were above or below the actual values, and to establish the control limits of the model. Tracking signals are calculated by dividing the Running Sum of Forecast Errors (RSFE) by the MAD (12:88). Table 5-11 lists the tracking signals for the unit learning curve model plotted by month. Appendix H provides the calculation of the tracking signals for each of the three types of models discussed above. The unit learning curve tended to project negative tracking signals as fourteen of the twenty-one calculations were negative. That is, the values (discount usage rate) predicted by the learning curve tended to be higher than the actual values.

The tracking signal also may be used to determine whether the model's forecasts are in control. According to Chase and Aquilano, acceptable limits for the tracking signal vary dependent on the level of demand being forecasted (12:88). High volume items should be monitored to a greater extent than low volume items. Chase and Aquilano provide a set of control limits which is presented in Table 5-12 (12:88). This table is extremely stringent, however, as the model being evaluated would have little discretionary value beyond ± 2 MADs. Plossl and Wight take a practitioner's view of this problem and suggest that "acceptable maxima for the tracking signal run between four and eight [38:107]." They further indicate that high

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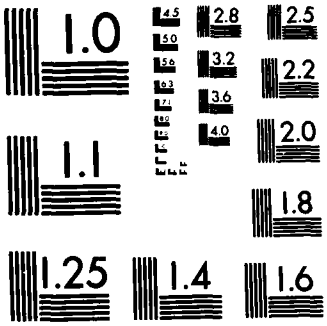

1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

TABLE 5-11

TRACKING SIGNALS

SATO Location	Learning Curve Plotted by Month
Barksdale	-3
Chanute	2
Charleston	-4
Griffiss*	-2
Hanscom	.9
Homestead	1.1
Keesler	-1.4
Kirtland	-2.0
Lackland	1.3
Los Angeles	-.4
Lowry	-4
March	2
Maxwell*	-2
McGuire	-2
Offutt	-3
Patrick	3
Scott	-2.7
Sheppard	-4
Vandenberg	1.7
Wright-Patterson	-4
Aggregate	-2

Note: *These tracking signals changed their direction from positive to negative due to the change in what constituted a discount as of March 1, 1982.

TABLE 5-12

CONTROL LIMITS

Number of MADs	Related Number of Standard Deviations	Percentage of Points Lying Within Control Limits
±1	0.798	57.048
±2	1.596	88.946
±3	2.394	98.334
±4	3.192	99.856

volume items should require a maximum tracking signal of ± 4 MADs "to trigger an early review of the forecast [38:107]." The authors examined the tracking signals calculated from the unit learning curve predicted values (rates of discount usage), and confirmed that the tracking signals for the SATO locations and their aggregate fell within the ± 4 MADs control limit. Therefore, the model's forecasts are in control, and provide reasonable forecasts of the rates of discount usage.

Summary

The investigation of learning curve theory as a predictor for airline discount rate usage revealed positive results. The data obtained from twenty SATO locations for a sixteen-month period reflected discount rate growth in all bases with the possible exception of Maxwell AFB, Alabama. Plots of the learning curves on log-log paper and in real number dimensions provided pictoral evidence of the progressive improvement of SATO locations in obtaining a greater number of discounts. While highly variant learning curve slopes were obtained through the use of two packaged computer programs, the Plot 50 program was chosen as the predictive tool due to its close resemblance to the graphically derived rates of learning. The unit learning curve plotted by month more accurately projects the rates of discount fare usage than the learning curve plotted by units, and the best fit regression models. Nearly 62 percent (thirteen out of twenty-one populations) of the forecasted rates of discount usage fall within MAD values of five when compared to the actual rates of discount usage. One hundred percent of the tracking signals fall within the established control limit of ± 4 MADs demonstrating the reasonableness of the unit learning curve projections.

Analysis of Research Question--Part Two

The second part of the research question currently is untestable due to delays in the contractual process of the TMSP. Nonetheless, this research provides a proposed set of criteria, a benchmark model, against which the results of the TMSP test data may be compared. Because this study demonstrated that the performance of Wright-Patterson AFB SATO was not generalizable to the Air Force enhanced SATO population as represented by the sample under study, the authors chose McGuire AFB, New Jersey, as the benchmark base for test criteria. Having similar missions, and belonging to the same command, McGuire and Travis AFBs have a number of common factors. However, it is recognized that while both bases have access to cross-country discount fares, there are probably numerous variations in discount availability. The examination of those variations lies outside the realm of this study. In addition to the cost criteria provided for McGuire, cost criteria also are provided for the twenty-base aggregate. The aggregate provides a macro view of the Air Force SATO program.

Table 5-13 provides a listing of unit learning curve by month projections for McGuire AFB from the thirteenth through the twenty-ninth month. This time frame encompasses the predicted SATO performance from 1 February 1982 to 31 July 1983. The learning curve provides a steadily declining rate of failure to use discount fares. This decline reflects the trend examined in part one of the research question. There are limitations and problems associated with this trend, such as seasonality, which will be examined in Chapter VI.

Table 5-14 provides a listing of unit learning curve projections for the aggregate of the selected twenty SATO locations. While these projections provide an outlook for the months ahead, it is important to realize that

TABLE 5-13

MCGUIRE DISCOUNT USAGE CONTROL LIMITS

Month	10% Less Units	Same Units	10% Greater Units
13	23.5	23.5	23.5
14	23.1	23.0	22.9
15	22.5	22.4	22.3
16	21.9	21.7	21.6
17	21.3	21.1	20.9
18	20.8	20.6	20.4
19	20.5	20.2	20.0
20	20.2	19.9	19.6
21	19.9	19.6	19.3
22	19.6	19.3	19.0
23	19.3	18.9	18.6
24	19.0	18.7	18.3
25	18.8	18.5	18.1
26	18.6	18.3	17.9
27	18.4	18.0	17.6
28	18.1	17.7	17.3
29	17.9	17.4	16.9

TABLE 5-14

AGGREGATE DISCOUNT USAGE CONTROL LIMITS

Month	10% Less Units	Same Units	10% Greater Units
13	29.2	29.2	29.2
14	28.9	28.8	28.7
15	28.5	28.4	28.3
16	28.1	28.0	27.9
17	27.8	27.6	27.5
18	27.4	27.3	27.1
19	27.2	27.0	26.8
20	26.9	26.6	26.4
21	26.6	26.3	26.1
22	26.3	26.0	25.8
23	26.0	25.7	25.5
24	25.8	25.5	25.3
25	25.6	25.3	25.1
26	25.4	25.1	24.8
27	25.3	24.9	24.6
28	25.1	24.7	24.4
29	24.9	24.5	24.2

the aggregate has inherent limitations. The aggregate of the twenty bases does not exist in and of itself. It is a study and a projection of averages. As such, its study should be conducted accordingly.

Although the learning curve model plotted by unit was not the most effective means of predicting the rate of discount fare usage, it may be an integral tool in the prediction of discount fare usage when passenger traffic increases or decreases by a significant amount. Tables 5-13 and 5-14 provide control limits for passenger traffic when that traffic varies from 10 percent below to 10 percent above the previous year's traffic levels. The key to this control device may lie in the development of an effective method of predicting the passenger traffic levels.

Subjective Analysis

An overview of SATO and TMSP programs was presented in Chapter II. This section contains a subjective analysis of the services provided under each program. The services discussed are those presented in the TMSP Request for Proposal and SATO's Memorandum of Understanding.

Prior to the development of TMSP, the travel agent concept was tested by a few individual government organizations. The results from the Department of Labor and General Services Administration tests are summarized and presented in this section. Next, a chart developed by the authors to provide a tool for comparison of services rendered by the TMSP and SATO is presented. Following this chart is a comparative analysis of these services.

<u>Evaluation of Previous Tests</u>

Two forms of regulation prohibited the governmental use of travel agencies. A Government Accounting Office (GAO) regulation prohibited the use of travel agencies by governmental activities except the State Department. The exception granted to the State Department allowed the use of travel agencies in and between overseas areas (28). The second prohibition took the form of agreements between the Air Traffic Conference (ATC) and travel agencies which prevented the travel agencies from collecting commissions on government-sponsored travel (28). This agreement was sanctified by the Civil Aeronautics Board (CAB). The argument of the ATC for such a prohibition was based on the assertion that travel agencies were paid a commission strictly for their promotion of airline travel (4:11-12).

The movement towards deregulation, and the pressure provided by agencies such as the American Society of Travel Agents, influenced the CAB's reconsideration of the ATC/travel agencies' agreements illustrated above. Under the CAB's Competitive Marketing Study, the CAB found the government-sponsored travel provision to be improper. In the Spring of 1981, the CAB rescinded its approval of the agreement (28). The CAB further stated that any future restrictions of this nature were a matter for individual airline and travel agency consideration (28).

In 1981, the Department of Labor performed a test examining the potential use of travel agencies in the Employment and Training Administration in Washington, D.C. (53:i). The O. Roy Chalk Travel Agency operated under contract providing a centralized ticketing and reservations function for the Employment and Training Administration (53:i). Prior to this experiment, airline, hotel, and car rental reservations were made by the individual traveller. This was the first time a central travel function operated within the Department of Labor. This centralized travel function was reported as a general success (53:5). Mr. Bill McDade, Director of Policy Development and Analysis Division, Office of Travel and Management, General Services Administration, went even further to say the Department of Labor's test was a "resounding success [28]." The test, however, was not without its problems. Initially, the test had to be terminated as the O. Roy Chalk Travel Agency withdrew from the test program on December 31, 1981 (24:16). This travel agency withdrew due to the difficulty encountered in the collection of commissions from the airlines and in maintaining a sufficient cash flow to sustain the agency during the government reimbursement process.

At one time during the test, this agency was over $100,000 in the arrears on making collections from the government (52:2). A large part of the travel agency's revenue was provided by commissions based upon tickets not requiring Government Travel Requests (GTRs). The travel agency reported at least a $30,000 loss at the time of their withdrawal from the program (24:16). A second major problem dealt with the high turnover of labor during the test (53:2). The labor turnover rate may be characteristic of the travel agent industry.

The General Services Administration (GSA) initiated its own test in April 1982. The test was designed to examine the feasibility of a travel service operating within the government. GSA management felt that SATOs produced an inferior service (28), and they believed that travel agencies may provide a higher level of service to the traveller. (The SATOs servicing the GSA were not "enhanced" as the Air Force SATOs have been.) The choice of travel agencies was based on their submission of statements of work, and the subsequent negotiation between GSA and the travel agency (28). Establishing test sites in such locations as Washington, D.C., Dallas, Denver, Kansas City, Baltimore and Omaha, the GSA sought performance results from a cross-section of its operations. Multiple test sites were also established since GSA management did not want to rely on the results of a single test site (28).

GSA attempted to correct some of the deficiencies discovered during the Department of Labor test by consolidating transactions into one Government Transportation Request (GTR, Standard Form 1169). In this manner, the GSA sought to expedite the reimbursement process, and to provide cash directly to the travel agents. It was then up to the travel agents to use this money as "leverage" with which to negotiate commissions with the airlines (28). While some travel agents refused to submit statements of work based upon past prohibitions on government travel commissions, a number of aggressive travel agents realized the far-reaching benefits of such a proposition (28). Hence, the GSA had little trouble contracting travel services at each of its designated locations. Although the GSA has instituted these capital flow changes, the results of the test remain to be seen. The questions of sufficient capital and labor turnover remain from the previous Department of Labor test. The nature of the GSA test results may indeed depend on the answers to these questions.

Comparative Analysis

The enhanced Scheduled Airline Traffic Office (SATO) and the Travel Management Services Programs (TMSP) possess distinct advantages over one another (see Table 5-15). The following analysis assumes the services offered by either program are functional and necessary. As will be discussed later in Chapter VI, this assumption deserves future study.

The Scheduled Airline Traffic Office program possesses a tremendous experience advantage over the TMSP program. Although the SATO was only recently enhanced in 1979, its background in airline operations and knowledge of the government's need for those operations is extensive. This is reflected in the experience records of SATO employees. SATO managers possess an average of twenty-six years of experience in the airline industry, and nineteen of those are within the SATO (41). The SATO agent averages twenty years of airline experience, and twelve of those are within the SATO (41). While pay levels of SATO agents and managers were not readily available, as they vary depending on the sponsoring airline, they are reportedly higher than that of the average travel agency (41). This lends credence to the SATO's assertion of industry expertise. This advantage tends to become stronger in light of the Department of Labor test results where a high rate of labor turnover was the norm for the contracted travel agency.

The second major advantage of the enhanced SATO program concerns its organizational structure. The SATO

TABLE 5-15

COMPARISON OF THE SCHEDULED AIRLINE TRAFFIC OFFICE AND THE TRAVEL MANAGEMENT SERVICES PROGRAM BY SERVICES RENDERED

Services Performed	SATO	TMSP
Hours of operation	Operate during normal business hours in the installation and additional hours as required for valid DOD travel needs as mutually agreed upon by the TMO and SATO manager.	Twenty-four-hour a day year-round official travel support. Normal hours established in conjunction with TAFB TMO.
Passenger or freight	Will assist the TMO in routing freight shipments in addition to passenger travel in the most *cost-effective manner*.	Designed for the official traveller only.
Insure maximum use of prevail-ing mode, lodging and rental vehicle discounts	Provide lowest possible fares taking advantage of all discounts available; arrange hotel accommodations, car rental services and other travel requirements in conjunction with official travel.	Recommend the most cost-effective mode capable of satisfying mission require-ments as first option; e.g., bus-250 miles or less; provide lodging and rental car support giving priority to those companies offering best govern-ment or travel agent negotiated con-tracts.
Reference library	Complete set of Airline Tariff Publishing Company's rule and fares tariffs for air transportation and other such tariffs as required for other travel modes which the SATO is authorized to represent; current issues of guides for modes which the SATO represent.	Up-to-date mode information, lodging information and rental car information.

TABLE 5-15--Continued

Services Performed	SATO	TMSP
Process refunds	Process refunds and adjustments the day the unused ticket is received.	Initiate refund application within five working days of receipt of unused ticket.
Government quarters	Currently does not provide this service.	Provide availability of and make reservations for government quarters at four CONUS installations.
Management reports	Prepare monthly summary reports on the cost savings due to SATO routing and use of discount fares and nonuse codes by base organizations.	Prepare summary monthly reports on the use and costs of lodging, rental vehicles arranged by the travel agent and all air, rail and bus tickets issued by the travel agent.
Disputes	May be handled between local TMO and SATO manager.	TMO services as TRCO; must discuss problems with contracting officer who carries problems to the travel agent.
Wartime	The ATA will provide emergency services to DOD upon request in response to a national emergency.	Wartime capability limited.
Office space	Furnished by the government; offset by management reports being prepared at no charge by the ATA.	No charge by government for office space; no charge to government for management reports.

TABLE 5-15--Continued

Services Performed	SATO	TMSP
Unofficial traveller	Offer unofficial reservation and ticketing services for all carriers on impartial basis, to include, but not limited to, individual tickets and tour services providing the lowest fares which meet the traveller's requirements.	Provide complete travel service and support to TAFB and other DOD personnel requesting leave/vacation arrangements.

exists as an entity managed in cooperation between the Air Transport Association (ATA) and the United States Air Force Directorate of Transportation. As such, there is a direct link between the ATA and the Directorate of Transportation, and between the SATO and the Traffic Management Officer (TMO) (16). A management information system has been established whereby the monthly sales and discount usage reports are sent by each SATO through the ATA to the Directorate of Transportation. Any discrepancies found in the report, or any management problems detected, may then be channeled back through the ATA. The system possesses a minimum number of managerial levels, and has developed a strong functional relationship between the ATA and the Air Force (43). It is this system-like operation that lends itself to spinoffs such as the SATO satellite program, where bases unable to justify an independent SATO may still enjoy the services of a SATO.

The system-like operation of the SATO may be difficult to achieve under the TMSP. The system can become fragmented since each base may opt for a contract with a travel agency, a SATO, or an independent airline to provide the travel service. Although the travel agencies may gradually establish a centralized reporting system, much like their current plan for ticket payment (the Area Settlement Plan), this supposes that all Air Force travel services will be travel agents belonging to the American

Society of Travel Agents, Inc. (ASTA) (4:17). Additionally, the relationship between the Air Force TMO and the travel agent under the TMSP becomes more complicated than under the enhanced SATO program. Under the current enhanced SATO program, the SATO operates in compliance with a Memorandum of Understanding (MOU). The MOU allows direct discussion between the SATO manager and the Traffic Management Officer. In contrast to this relationship, the travel agency will operate under a contract. This relegates the TMO to the position of a technical representative of the contracting officer (TRCO). As a TRCO, the TMO will have to conduct all TMSP business through the contracting officer. A minimum of one managerial level is therefore added per installation, complicating the entire system communication process. The system then becomes a series of fragmented agencies that would not easily allow technological spinoffs such as the satellite program.

The third, and final, advantage of the SATO is its capital position. The SATO located at Wright-Patterson AFB, the largest in the Air Force, handles transactions of over 50,000 dollars per day (47). The speed of the federal reimbursement process does not permit real time payment of transactions. As a result, the travel operation requires a substantial sum of operating capital. As a large operation funded by ATA affiliated airlines, the SATOs possess the necessary capital. In contrast, travel agencies may not possess the capital to operate effectively at some Air Force installations. This problem forced the withdrawal of the contracted agency's participation in the previously reported Department of Labor test. The results of the GSA travel service test should provide vital information regarding operating capital needs of travel agents in the governmental environment.

The Travel Management Services Program provides two advantages relative to the SATO program. First, the TMSP provides an increased level of service. The contracted travel agency may provide tickets and reservations for surface modes of transportation, including bus and rail, in addition to airline travel. Travel agency personnel are also capable of providing reservations for hotel and car rentals. Travel agencies belonging to ASTA employ certified personnel. That is, travel agency personnel undergo a three and a half year educational and training program familiarizing employees with all facets of the travel industry (36). While the experience and pay levels of travel agency personnel may not be as high as those in the SATOs, they possess more experience across a variety of modal choices. Under the TMSP, a travel service may be provided by either a SATO, travel agency, or independent airline. This level of competition will likely cause the SATOs to heighten its level of service. An example of this potential trend is evident in the current GSA test program.

An article in Travel Weekly describes the efforts of an Atlanta-based SATO to enhance its service to the GSA in light of the GSA test (9:32). Furthermore, SATOs and the ATA are positioning themselves for upcoming contract bids with the GSA in a number of other locations (9:32-33). While the travel agency may not win the contract, its participation in the contract award process will insure a higher level of service.

The second advantage of the TMSP program concerns the number of business contracts made available to American small businesses, defined as 500 employees or less for the purpose of the TMSP test (31). While this may not be a specific goal of the travel management program, it is a goal sought by the federal government as a whole. In a speech to the Greater Philadelphia Chapter of the National Contract Management Association, Robert J. Trimble, Assistant Administrator for Contract Administration, Office of Federal Procurement Policy, emphasizes the importance of federal contracts as a means for reflecting the needs and social fabric of this country (49:12-14).

One other area deserves attention in this study of comparative travel program advantages. That is, pro-SATO enhancement and pro-TMSP supporters claim their programs are the most equitable. The pro-SATO contingent asserts the travel agency possesses little incentive to obtain the lowest fare. They claim the greater the fare chosen, the greater the commission received by the travel agency (47; 16). On the other hand, travel agency proponents claim they are more equitable as the airline sponsoring the SATO is more likely to obtain the most passengers. Additionally, they assert there is a lack of incentive in the SATO program to obtain the lowest fare for the same reasons as their critics espouse (4:17). After examining the arguments of the proponents involved in the debate, the matter of equity becomes a moot issue. Under either program, it is the review of passenger itineraries by qualified TMO personnel that determines the effectiveness of the system.

Conclusion

This subjective analysis offers a brief examination of travel service experiments in the Department of Labor and in the General Services Administration. The Department of Labor travel service test provided general support for the use of centralized travel services within the government. However, the test also highlighted the existing problems of labor turnover and a lack of sufficient operating capital within the travel agent industry. A comparative analysis was provided highlighting the advantages of the SATO and TMSP programs. While both programs offer advantages to the Air Force, the enhanced SATO program would seem to provide the greater benefit under the current contracting and transportation operating structures. Conclusions and recommendations, based on the research performed, are presented in Chapter VI and provide the summary of this report.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Introduction

A principal objective of this study was to evaluate learning curve theory as a tool for predicting travel management costs. Following this evaluation, the authors attempted to provide preliminary information regarding the use of learning curve projections as comparative criteria to judge the forthcoming Travel Management Services Program (TMSP) test at Travis AFB, California. This chapter provides the conclusions reached after examining the aforementioned research objectives and associated two-part research question, the limitations of the learning curve used in this study, and recommendations for future research.

Conclusions

The conclusions section of this chapter follows the original twofold research question. Additionally, a third category of conclusions evaluates the TMSP test program *vis a vis* the current Air Force enhanced SATO program.

Initially, this work sought to answer the question as to whether learning curve theory provided a tool for predicting travel management costs. The authors used the

Rate of Discount Usage Variable to operationalize travel management costs. The rates of discount usage for the sample of twenty SATO locations and their aggregate were predicted based on learning curves plotted by month and the percentage of discount usage. These projected rates of discount usage were compared to the actual results. Calculating the mean absolute deviations (*MADs*) and *tracking* signals for each of the twenty-one data sets demonstrated that the model predicted the actual rates of discount usage within ± 4 MADs, and that the model was in control (i.e., that is, provides reasonable results). The latter conclusion must be viewed with caution, however, as a maximum of only four data points was examined per location due to the limited data base. Nonetheless, the authors did find the learning curve to be adaptive to the travel management industry. The learning curve certainly may be used to predict airline passenger discount rate usage by the Air Force enhanced Scheduled Airline Traffic Offices with relative accuracy.

In addition to the determination of the learning curve model as a predictor of travel management costs, this investigation discovered a second major benefit of learning curve theory. That is, learning curve theory provides a superior management control and goal-setting device. For example, by simply examining the rates of discount usage in relation to its learning curve, the authors easily detected several aberrations in the data. Upon investigation of data aberrations at McGuire, Griffiss, and Maxwell Air Force Bases, the authors discovered a management information system problem. A change in the discount fare accounting system failed to provide a clear distinction between partial fares, which are fares entitling the Air Force to a full discount over a single "leg" of a trip, with a midlevel discounted fare that costs more than a fully discounted fare. This problem was reported to Major Larry Doak of the Air Force Directorate of Transportation. His communication of this problem to the Air Transport Association should provide clarifying guidance to SATOs Air Force-wide.

Learning curve theory may be used for goal setting and management control purposes in a number of ways at different managerial levels. At the Headquarters Air Force level, an aggregate learning curve may be used to provide a macro view of the SATO program and its continuing progress. Projections based on the aggregate curve should provide a relative trend or set of control limits to which the actual data may be compared. Major Air Commands would be able to develop learning curves for individual bases for similar trend analysis. At this level, learning curve control limits could direct management attention to significant increases or reductions in discount activity. Finally, individual Traffic Management Offices and SATO managers could manage their airline ticket operations more effectively by establishing realistic goals based on learning curve projections. Although the enhanced SATO program traditionally has been managed without established goals to prevent "gaming" of the system (43; 16), a set of realistic goals, trends or control limits still offer a multitude of managerial uses.

The second category of conclusions concerns the part of the research question addressing the use of the learning curve to establish criteria for the TMSP test. The establishing of comparative criteria is limited by the lack of TMSP test data with which to compare the projected rates of discount usage. The second half of the research question is therefore untestable at this time, and relies upon future research to determine the validity of this use of the learning curve. Nonetheless, the investigation yielded the following major conclusion.

The authors established that the nature of each SATO is unique. The individualized nature of the SATO may be due to its location, base mission, discount availability, quality of management personnel, and several other factors. For example, in an attempt to establish Wright-Patterson AFB (WPAFB) as a representative of the aggregate Air Force SATO population, the authors found the mean rates of discount usage from the twenty SATO locations to be classified in ten distinct groups in a Duncan's Range

Test performed at the .05 significance level. The WPAFB SATO mean was grouped with only three other bases, thus failing the criterion test that it be grouped with at least 51 percent of the sampled SATO locations. Further, the variance between learning curve slopes for each of the bases, as shown in Table 5-7; and the variance in the MADs and tracking signals, as shown in Tables 5-10 and 5-11; demonstrate the individuality of each of the twenty sampled SATO locations. Therefore, the authors concluded that each SATO location is unique in its performance results. This supports an assertion made by the WPAFB SATO manager during a personal interview (47). This conclusion is accompanied by several ramifications. First, this conclusion forced the dismissal of WPAFB as a suitable representative of the SATO population. In fact, the conclusion discourages any further attempts to choose a suitable SATO location from which to generalize. Secondly, the uniqueness of the bases requires an individual evaluation of SATO limitations in terms of management effectiveness. Comparative evaluations between two different SATO locations could be invalid, particularly if their means are classified in different groups by the Duncan's Range Test.

The third, and final, category of conclusions addresses the differences between the TMSP and the enhanced SATO program. As described in the comparative analysis in Chapter V, the TMSP provides a higher level of customer service through the addition of multimodal ticketing and reservations capabilities. The TMSP also affords the Air Force and the DOD the opportunity to provide a greater number of small business contracts. On the other hand, the SATO maintains advantages of personnel and managerial experience and minimal rates of labor turnover. The enhanced SATO system offers an integrated management system as opposed to the inherently fragmented nature of the TMSP. Finally, the SATO operates best within the constraints of current contracting and transportation operations. Direct communication between the Air Force Directorate of Transportation facilitates a manageable passenger travel system by minimizing the number of managerial levels. Under the current system, the SATO provides the optimal service in terms of manageability and stability. The TMSP must confront too many organizational and legal obstacles to be effective under the current system. This subject is discussed in greater length in the recommendations for future research portion of this chapter.

Research Limitations

Four major limitations were confronted in this study. These limitations involved data availability, the sensitivity of the learning curve to system changes, the relative accuracy of the unit learning curve model, and the assumption that McGuire and Travis AFBs belong to the same population. Each of these limitations will now be discussed.

The seemingly perpetual delays of the TMSP test prevented the pursuit of the second portion of the research question. Without TMSP test data, the authors were unable to test the validity of learning curve projections as transportation cost criteria. The TMSP test at Travis AFB, California is currently not expected to begin until after January 1, 1983 (31).

The second limitation of this research was inherent in the nature of the learning curve itself. That is, the learning curve was sensitive to changes in the system it attempted to predict. While it ably identified the discount classification change in March 1982, the learning curve model's rate of learning would have required a modification had it not been for an accommodating change in the basic data (see Table 5-10). When major system changes are made, the learning curve's rate of learning must also change.

The third limitation regards the relative accuracy of the learning curve model in predicting transportation costs. The unit learning curve plotted by rate of discount usage and month was found to predict the actual rate of discount usage with relatively strong accuracy. However, better models may exist as shown in the "best fit" analysis in Chapter V. In that analysis, the unit learning curve plotted by rate of discount usage and month produced the least maximum residual error in only two of the twenty-one populations. The major reasons for this relatively poor level of performance are that the learning curve plotted by month ignores the factors of seasonality, managerial quality, discount availability, and level of competition inherent at each SATO location. However, this model did provide superior predictions when compared to the learning curve model plotted by unit because of the unit model assumption that passenger traffic remained constant to the monthly traffic of the previous year. As suggested in the recommendations for future research, a regression model incorporating variables such as level of competition, level of passenger traffic, and seasonality may be a superior predictor of discount rate usage. Additionally, the learning curve was treated as a heuristic tool rather than in its strictest statistical form. The heuristic routine (Table 5-5) computes algebraic midpoints that do not possess the utmost accuracy. Computer routines, such as the Algebraic Lot Midpoint Unit Regression Analysis (ALMURA), are available to obtain more accurate midpoints (25:43). These routines may boost the accuracy of learning curve projections.

The fourth, and final, limitation concerns the assumption that McGuire and Travis AFBs are from the same population. In view of the conclusion that SATO locations are unique, this appears to be a weakened assumption. Nonetheless, pursuit of a regression model, as described above to explain more of the variance than the unit learning curve model, may permit a better comparison of the two bases. Since the travel agency operating at Travis AFB was covered under a grandfather clause allowing its operation at a government installation, there was no SATO data available to make an objective comparison to any SATO host base. Therefore, the comparison of Travis and McGuire AFBs remains a subjective one whether a learning curve or specially designed regression model is employed.

Recommendations

Four major recommendations for future research are offered in accordance with the twofold research question and the subjective analysis of the TMSP and the enhanced SATO programs. Initially, the successful testing of the learning curve as a predictor of transportation costs requires several iterations. With a maximum of four data points per base to verify this conclusion, further research is required to reverify the use of the learning curve for this purpose.

The second part of the research question was left unanswered as the TMSP test met with continual delay. A test of the learning curve projections as transportation cost criteria is required to fulfill the response to the posited research question. This test may be conducted in two ways. First, the test may be designed as originally proposed by this research. That is, the criteria established in this study by learning curve projections would be compared to the actual results of the TMSP test at Travis AFB, California. A second means of conducting the test may be to compare the results of the GSA test in aggregate to the learning curve projections of the Air Force aggregate. Results of the GSA test should become available in the first annual assessment of the test program in April 1983 (28). Either of these options would provide a more objective means for comparing the two programs.

Third, a regression model should be developed to predict transportation costs, and establish transportation cost criteria. Variables such as level of competition, discount rate availability, number of passengers, and seasonality should be used to explain the variance of the individual SATO performance. This model should be compared to the basic learning curve model used in this research. An assessment then may be made to determine the superiority of either model.

The final recommendation addresses whether the TMSP or the SATO is best for the Air Force. Throughout the research, the authors found a statement of need noticeably missing from the literature. The question surrounding this subjective analysis of which program best serves the United States Air Force centers on the service required and expressed in a need statement. If the service required includes multimodal ticketing and reservations, car rentals and hotel reservations, then the TMSP must be given full consideration. If these services are unnecessary, then there is little need of testing the TMSP. As Hay suggests, the first step in the planning process should be an expression of a statement of need (22:475).

Once a statement of need is expressed, an examination of transportation cost criteria becomes useful. Comparing the TMSP actual results to the criteria based upon learning curve or specially designed regression model projections provides an insight to the competitive nature of the two programs. If the TMSP is competitive in terms of discount rate usage, or some other selected variable(s), then the TMSP should be analyzed in terms of its overall performance.

The comparative advantage analysis suggested above should include a prioritization of program qualities, and assume that either program, TMSP or SATO, was operating in a supportive environment. As discussed in the subjective analysis and conclusions of this study, there are advantages to either program. Prioritization of these advantages, such as level of service and system-like nature of the SATO, should be made to ascertain the relative standing of the two programs. Essential to the completeness of this analysis should be consideration of the TMSP under a contractual system operating by exception. That is, accommodating legislation should be considered to hasten the federal system of reimbursement and redirect the flow of communication between the contractor (travel management service) and the beneficiary (Traffic Management Officer). Under the current contractual structure, the TMSP cannot equitably compete since the contracting system is inherently supportive of large travel management firms that have the operating capital to function within a slow reimbursement system. The TMSP/SATO comparative analysis should address these system changes.

Summary

This chapter provided conclusions, limitations of this research, and recommendations for future research. This study demonstrated that learning curve theory may be used for predicting travel management costs. The applications of the learning curve to Air Force travel management agencies are numerous. Learning curve projections serve as excellent management and control tools as they allow for the establishment of realistic goals, trends and control limits. These projections also may serve as excellent budgetary and planning tools to the travel manager.

While there are limitations to this study, future research may aid in eliminating or reducing the importance of those limitations. The authors recommend replications of this study to affirm/deny the learning curve as a predictor for future travel costs; comparisons of the TMSP or GSA test data to the travel cost criteria in this study; regression models be developed to better predict travel costs; and evaluations of the TMSP and SATO programs be performed after a statement of need is expressed.

APPENDICES

APPENDIX A

DEFINITIONS

Air Transport Association of America (ATA)--the trade and service organization representing certain U.S. air carriers (29:B-1).

Airline Discount--airline ticket rates offered by airline carriers which are lower than the standard coach fare between a specified origin and destination.

American Society of Travel Agents, Inc. (ASTA)--professional travel trade organization whose primary goal is to safeguard the travelling public against unethical practices and to promote the interest of the travel agency industry.

Automated Reservation System--comprised of a Cathode Ray Tube (CRT) linked to a carrier's central processing computer for routing passengers, confirming reservations, quoting fares, and printing tickets.

Government Transportation Request (GTR)--a written request of the United States Government (Standard Form 529) for the purpose of procuring transportation, accommodations, or other services chargeable to the government. GTRs are to be used for official travel only.

Interagency Travel Management Improvement Project--an effort designed to analyze government travel and make recommendations for improving the travel management practices of the federal government based upon their findings.

Learning Curve--the reduction in a chosen variable (e.g., labor hours, dollar cost, percentage of passengers travelling with discounted fares), at a constant rate over the quantity of units produced (e.g., aircraft, refrigerators, airline reservations/ tickets).

Official Travel--the Joint Travel Regulation defines official travel as

> . . . a travel status while performing travel away from their permanent duty station, upon public business, pursuant to competent travel orders, including delays for the purpose of qualifying for reduced travel fares and other necessary delays enroute incident to the mode of travel and periods of necessary temporary or temporary additional duty [51:3-13].

Scheduled Airline Transportation Office (SATO)--the SATO provides service including reservations and ticketing with respect to air travel on government transportation requests (GTR/SF 1169).

> This includes supplying information regarding services of airlines, selling airline tickets to service affiliated personnel, arranging for refunds and adjustment for airline tickets purchased for cash or GTR/ SF1169 when partially or wholly unused, and assist with the physical movement of unofficial air passenger transportation as may be required by the Base Commander [30:1].

Standard Travel Advance Reservation System (STARS)--acronym previously represented the TMSP concept described below.

Travel Management--the monitoring and control of dollars spent for DOD travel.

Travel Management Services Program (TMSP)--the TMSP is a test program broadening the scope of travel services offered to DOD personnel. The program expands the type of agencies capable of managing an installation's travel program from the SATO to the SATO, travel agency, and other independent travel organizations. Further, the program extends the present enhanced SATO air-dominated program into the rail and bus modes of passenger transportation. Additionally, the TMSP requires the travel management agency to arrange reservations.

APPENDIX B

BREAKDOWN OF ESTIMATED FEDERAL TRAVEL SAVINGS

INTERAGENCY TRAVEL MANAGEMENT IMPROVEMENT PROJECT
DATA SUMMARIES

Summary of Selected Travel Characteristics (1)

Number of trips	- 16 million
Direct travel expenditures (object class 21)	$3,200 million
Number of travel vouchers	10 million
Voucher processing costs	$400 million
Outstanding travel advances	$143 million

Summary of Savings Estimates (2)	Direct Travel (OC 21) Expenditures	Travel-related Administrative Costs
Require Federal travelers to purchase common carrier tickets through SATOs or travel agents to assure greatest use of GSA contract air service and other discount fares	$116.2 million	
Consolidate carrier payments and reduce the number of GTRs used		$14.8 million
Streamline voucher processing procedures by:		
- adopting a locality-based flat rate per diem policy		46.1 million
- restricting supervisory reviews by two		0.1 million
- examining in full only those vouchers over $500 and examining a random sample of those vouchers under $500		21.7 million
Increase controls over travel advances and reduce the amount of advances outstanding		2.8 million
	$116.2 million	$85.5 million

Total Proposed Estimated Gross Savings (3) $201.7 million

Notes (1) Travel expenditures and advances are for FY 1980; the remaining data are for FY 1979.

(2) Estimates based on FY 1982 budget projections.

(3) Many savings are obtainable at no cost or at nominal costs that can be absorbed as a part of ongoing activities. There also are indeterminate savings from some recommendations that would offset indeterminate costs.

APPENDIX C

DATA BASE

AGGREGATE

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	17361	7232	17361	5787.0	5787.0	41.7	58.3
2	18544	9075	53266	9272.0	26633.0	48.9	51.1
3	19607	10092	72873	9803.5	63069.5	51.5	48.5
4	20280	10918	93153	10140.0	83013.0	53.8	46.2
5	21030	12394	114183	10515.0	103668.0	58.9	41.1
6	19475	12085	133658	9737.5	123920.5	62.1	37.9
7	20105	13603	153763	10052.5	143710.5	67.7	32.2
8	21648	15132	175411	10824.0	164587.0	69.9	30.1
9	23725	16782	199136	11862.5	187273.5	70.7	29.3
10	25022	17494	224158	12511.0	211647.0	69.9	30.1
11	20882	14977	245040	10441.0	234599.0	71.7	28.3
12	18430	13774	263470	9215.0	254255.0	74.7	25.3
13	21862	16092	285332	10931.0	274401.0	73.6	26.4
14	23586	17704	308918	11793.0	297125.0	75.1	24.9

BARKSDALE

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	417	208	417	139.0	139.0	49.9	50.1
2	337	118	754	168.5	585.5	35.0	65.0
3	238	105	992	119.0	873.0	44.1	55.9
4	183	93	1175	91.5	1083.5	50.8	49.2
5	335	194	1510	167.5	1342.5	57.9	42.1
6	363	198	1873	181.5	1691.5	54.5	45.5
7	418	287	2291	209.0	2082.0	68.7	31.3
8	427	282	2718	213.5	2504.5	66.0	34.0
9	499	316	3217	249.5	2967.5	63.3	36.7
10	289	180	3506	144.5	3361.5	62.3	37.7
11	230	124	3736	115.0	3621.0	53.9	46.1
12	389	262	4125	194.5	3851.0	67.4	32.6
13	316	232	4441	158.0	4283.0	73.4	26.6
14	410	269	4851	205.0	4875.0	65.6	34.4
15	458	350	5309	229.0	5080.0	76.4	23.6

CHANUTE

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	454	163	454	151.0	151.0	35.9	64.1
2	613	240	1067	306.5	760.5	39.2	60.8
3	549	352	1616	274.5	1341.5	64.1	35.9
4	670	574	2286	335.0	1951.0	85.7	14.3
5	356	356	2642	178.0	2464.0	100.0	0
6	362	362	3004	181.0	2823.0	100.0	0
7	327	249	3331	163.5	3167.5	76.1	23.9
8	547	441	3878	273.5	3604.5	80.6	19.4
9	384	291	4262	192.0	4070.0	75.8	24.2
10	294	255	4556	147.0	4409.0	86.7	13.3
11	487	406	4962	243.5	4799.5	83.4	16.6
12	416	368	5378	208.0	5170.0	88.5	11.5
13	502	433	5880	251.0	5629.0	86.3	13.7
14	470	420	6350	235.0	6115.0	89.4	10.6

CHARLESTON

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	137	8	137	45.7	45.7	5.8	94.2
2	144	29	281	72.0	209.0	20.1	79.9
3	180	28	461	90.0	371.0	15.6	84.4
4	155	18	616	77.5	538.5	11.6	88.4
5	219	67	835	109.5	725.5	30.6	69.4
6	198	95	1033	99.0	934.0	48.0	52.0
7	249	114	1282	124.5	1157.5	45.8	54.2
8	1051	569	2333	525.5	1807.5	54.1	45.9
9	882	527	3215	441.0	2774.0	59.8	40.2
10	954	595	4169	477.0	3692.0	62.4	37.6
11	818	426	4987	409.0	4578.0	52.1	47.9
12	671	351	5658	335.5	5322.5	52.3	47.7
13	919	536	6577	459.5	6117.5	58.3	41.7
14	714	480	7291	357.0	6934.0	67.2	32.8
15	1003	734	8294	501.5	7658.0	73.2	26.8
16	816	523	9110	408.0	8555.5	64.1	35.9

GRIFFISS

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	614	72	614	205.0	205.0	11.7	88.3
2	608	48	1222	304.0	918.0	7.9	92.1
3	687	53	1909	343.5	1565.5	7.7	92.3
4	632	119	2541	316.0	2225.0	18.8	81.1
5	555	145	3096	277.5	2818.5	26.1	73.9
6	566	117	3662	283.0	3379.0	20.7	79.3
7	744	291	4406	372.0	4034.0	39.1	60.9
8	781	393	5187	390.5	4796.5	50.3	49.7
9	514	233	5701	257.0	5444.0	45.3	54.7
10	1024	477	6725	512.0	6213.0	46.6	53.4
11	770	416	7495	385.0	7110.0	54.0	46.0
12	665	388	8160	332.5	7827.5	58.3	41.7
13+	779	498	8939	389.5	8549.5	63.9	36.1
14+	779	509	9718	389.5	9328.5	65.3	34.7

+Includes partially discounted fares accounted for as of 1 March 1982.

HANSCOM

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	1258	195	1258	419.3	419.3	15.5	84.5
2	879	224	2137	439.5	1697.5	25.5	74.5
3	1005	306	3142	502.5	2639.5	30.4	69.6
4	1136	501	4278	568.0	3710.0	44.1	65.9
5	1311	637	5589	655.5	4933.5	48.6	51.4
6	1341	773	6930	670.5	6259.5	57.6	42.4
7	1318	907	8248	659.0	7589.0	68.8	31.2
8	1237	880	9485	618.5	8866.5	71.1	28.9
9	1371	1052	10856	685.5	10170.5	76.7	23.3
10	1611	1212	12467	805.5	11661.5	75.2	24.8
11	1288	1049	13755	644.0	13111.0	81.4	18.6
12	928	708	14683	464.0	14219.0	76.3	23.7
13	1365	1112	16048	682.5	15365.5	81.5	18.5
14	1151	981	17199	575.5	16623.5	85.2	14.8
15	1636	1219	18835	818.0	18017.0	74.5	25.5
16	1485	1192	20320	742.5	19577.5	80.3	19.7

HOMESTEAD

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	315	180	315	105.0	105.0	57.1	42.9
2	477	364	792	238.5	553.5	76.3	23.7
3	353	253	1145	176.5	968.5	71.7	28.3
4	411	337	1556	205.5	1350.5	82.0	18.0
5	387	294	1943	193.5	1749.5	76.0	24.0
6	331	267	2274	165.5	2108.5	80.7	19.3
7	335	256	2609	167.5	2441.5	76.4	23.6
8	321	233	2930	160.5	2769.5	72.6	23.1
9	242	153	3172	121.0	3051.0	63.2	27.4
10	350	269	3522	175.0	3347.0	76.9	36.8
11	319	216	3841	159.5	3681.5	67.7	32.3
12	260	214	4101	130.0	3971.0	82.3	17.7
13	367	252	4468	183.5	4284.5	68.7	31.3
14	380	271	4848	190.0	4658.0	71.3	28.7

KEESLER

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	648	287	648	216.0	216.0	44.3	65.7
2	616	317	1264	308.0	956.0	51.5	48.5
3	685	369	1949	342.5	1606.5	53.9	46.1
4	902	498	2851	451.0	2400.0	55.2	44.8
5	889	498	3740	444.5	3295.5	56.0	44.0
6	848	481	4588	424.0	4164.0	56.7	43.3
7	786	480	5374	393.0	4981.0	61.1	38.9
8	697	487	6071	348.5	5722.5	69.9	30.1
9	658	466	6729	329.0	6400.0	70.8	29.2
10	668	488	7397	334.0	7063.0	73.1	26.7
11	609	456	8006	304.5	7701.5	74.9	25.1
12	425	293	8431	212.5	8218.5	68.9	31.1
13	606	460	9037	303.0	8734.0	75.9	24.1
14	596	480	9633	298.0	9335.0	80.5	19.5
15	844	597	10477	422.0	10055.0	70.7	29.3
16	745	537	11222	372.5	10849.5	72.1	27.9

KIRTLAND

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	918	721	918	306.0	306.0	78.5	21.5
2	1039	826	1957	519.5	1437.5	79.5	20.5
3	1020	794	2977	510.0	2467.0	77.8	22.2
4	1029	842	4006	514.5	3491.5	81.8	18.2
5	1140	973	5146	570.0	4516.0	85.4	14.6
6	993	884	6139	496.5	5642.5	89.0	11.0
7	1221	1109	7360	610.5	6749.5	90.8	9.2
8	1327	1186	8687	663.5	8023.5	89.4	10.6
9	1072	988	9759	536.0	9223.0	92.2	7.8
10	745	697	10504	372.5	10131.5	93.6	6.4
11	1151	1080	11655	575.5	11079.5	93.8	6.2
12	1120	1072	12775	560.0	12215.0	95.7	4.3
13	1300	1274	14075	650.0	13425.0	98.0	2.0
14	1153	1097	15228	576.5	14651.5	95.1	4.9

LACKLAND

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	2391	2128	2391	797.0	797.0	89.0	11.0
2	3652	3206	6043	1826.0	4217.0	87.8	12.2
3	3653	3174	9696	1826.5	7869.5	86.9	13.1
4	3088	2762	12784	1544.0	11240.0	89.4	10.6
5	3171	2957	15955	1585.5	14369.5	93.3	6.7
6	3009	2825	18964	1504.5	17459.5	93.9	6.1
7	3166	3041	22130	1583.0	20547.0	96.1	3.9
8	3664	3526	25794	1832.0	23962.0	96.2	3.8
9	3855	3741	29649	1927.5	27721.5	97.0	3.0
10	3823	3622	33472	1911.5	31560.5	94.7	5.3
11	2662	2560	36134	1331.0	34803.0	96.2	3.8
12	3089	3026	39223	1544.5	37678.5	98.0	2.0
13	2245	2189	41468	1122.5	40345.5	97.5	2.5
14	3577	3427	45045	1788.5	43256.5	95.8	4.2
15	2769	2683	47814	1384.5	46429.5	96.9	3.1

LOS ANGELES

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	785	216	785	262.0	262.0	27.5	72.5
2	799	290	1584	399.5	1184.5	36.3	63.7
3	1102	428	2686	551.0	2135.0	38.8	61.2
4	1089	673	3775	544.5	3230.5	61.8	38.2
5	963	654	4738	481.5	4256.5	67.9	32.1
6	1166	790	5904	583.0	5321.0	67.8	32.2
7	1120	832	7024	560.0	6464.0	74.3	25.7
8	900	674	7924	450.0	7474.0	74.9	25.1
9	1352	1096	9276	676.0	8600.0	81.1	18.9
10	1642	1412	10918	821.0	10097.0	86.0	14.0
11	1357	1203	12275	678.5	11596.5	88.7	11.3
12	1011	890	13286	505.5	12780.5	88.0	12.0
13	1500	1348	14786	750.0	14036.0	89.9	10.1
14	1325	1139	16111	662.5	15448.5	86.0	14.0
15	1783	1544	17894	891.5	17002.5	86.6	13.4
16	1795	1566	19689	897.5	18791.5	87.2	12.8

LOWRY

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	516	315	516	172.0	172.0	61.0	39.0
2	488	297	1004	244.0	760.0	60.9	39.1
3	549	365	1553	274.5	1278.5	66.5	33.5
4	681	481	2234	340.5	1893.5	70.6	29.4
5	724	541	2958	362.0	2596.0	74.7	25.3
6	675	506	3633	337.5	3295.5	75.0	25.0
7	567	425	4200	283.5	3916.5	75.0	25.0
8	576	458	4776	288.0	4488.0	79.5	20.5
9	653	550	5429	326.5	5102.5	84.2	15.8
10	771	631	6200	385.5	5814.5	81.8	18.2
11	645	527	6845	322.5	6522.5	81.7	18.3
12	572	497	7417	286.0	7131.0	86.9	13.1
13	590	525	8007	295.0	7712.0	89.0	11.0
14	705	618	8712	352.5	8359.5	87.7	12.3

MARCH

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	110	57	110	37.0	37.0	51.8	48.2
2	179	128	289	89.5	199.5	71.5	28.5
3	113	76	402	56.5	345.5	67.3	32.7
4	101	61	503	50.5	452.5	60.4	39.6
5	149	120	652	74.5	577.5	80.5	19.5
6	112	88	764	56.0	708.0	78.6	21.4
7	242	212	1006	121.0	885.0	87.6	12.4
8	328	300	1334	164.0	1170.0	91.5	8.5
9	231	217	1565	115.5	1449.5	93.9	6.1
10	157	135	1722	78.5	1643.5	86.0	14.0
11	210	192	1932	105.0	1827.0	91.4	8.6
12	183	169	2115	91.5	2023.5	92.3	7.7
13	276	246	2391	138.0	2253.0	89.1	10.9
14	276	237	2667	138.0	2529.0	85.9	14.1

MAXWELL

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	236	64	236	79.0	79.0	27.1	72.9
2	396	138	632	198.0	434.0	34.8	65.2
3	725	411	1357	362.5	994.5	56.7	43.3
4	804	281	2161	402.0	1759.0	35.0	65.0
5	618	115	2779	309.0	2470.0	18.6	81.4
6	393	127	3172	196.5	2975.5	32.3	67.7
7	695	284	3867	347.5	3519.5	40.9	59.1
8	770	320	4637	385.0	4252.0	41.6	58.4
9	656	256	5293	328.0	4965.0	39.0	61.0
10	412	197	5705	206.0	5499.0	47.8	52.2
11	540	196	6245	270.0	5975.0	36.3	63.7
12	612	295	6857	306.0	6551.0	48.2	51.8
13+	611	349	8104	623.5	7480.5	57.1	42.9
14+	833	482	8937	416.5	8520.5	57.9	42.1

+Includes partially discounted fares accounted for as of 1 March 1982.

McGUIRE

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	698	252	698	233.0	233.0	36.1	63.9
2	1257	370	2577	628.5	1326.5	29.4	70.6
3	1326	560	3903	663.0	3240.0	42.2	57.8
4	1769	608	5672	884.5	4787.5	34.4	65.6
5	1586	667	7258	793.0	6465.0	42.1	57.9
6	1168	567	8426	584.0	7842.0	48.5	51.5
7	1136	789	9562	568.0	8994.0	69.5	30.5
8	1158	906	10720	579.0	10141.0	78.2	21.8
9	960	761	11680	480.0	11200.0	79.3	20.7
10	1371	1103	13051	685.5	12365.5	80.5	19.5
11	1200	1007	14251	600.0	13651.0	83.9	16.1
12	1034	891	15285	517.0	14768.0	86.2	13.8
13+	1247	1024	16532	623.5	15908.5	82.1	17.9
14+	1208	1147	17740	604.0	17136.0	95.0	5.0

+Includes partially discounted fares accounted for as of 1 March 1982.

OFFUTT

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	520	325	520	173.0	173.0	62.5	37.5
2	586	385	1106	293.0	813.0	65.7	34.3
3	457	310	1563	228.5	1334.5	67.8	32.2
4	405	306	1968	202.5	1765.5	75.6	24.4
5	1365	990	3333	682.5	2650.5	72.5	27.5
6	991	717	4324	495.5	3828.5	72.4	27.6
7	756	578	5080	378.0	4702.0	76.5	23.5
8	1360	1021	6440	680.0	5760.0	75.1	24.9
9	2446	1785	8886	1223.0	7663.0	73.0	27.0
10	1644	1173	10530	822.0	9708.0	71.4	28.6
11	1130	906	11660	565.0	11095.0	80.2	19.8
12	1569	1267	13229	784.5	12444.5	80.8	19.2
13	847	714	14076	423.5	13652.5	84.3	15.7
14	2303	1910	16379	1151.5	15227.5	82.9	17.1
15	1463	1194	17842	731.5	17110.5	81.6	18.4

PATRICK

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	223	93	223	74.0	74.0	41.7	58.3
2	200	97	423	100.0	323.0	48.5	51.5
3	251	159	674	125.5	548.5	63.3	36.7
4	293	245	967	146.5	820.5	83.6	16.4
5	330	255	1297	165.0	1132.0	77.3	22.7
6	328	268	1625	164.0	1461.0	81.7	18.3
7	383	323	2008	191.5	1816.5	84.3	15.7
8	335	288	2343	167.5	2175.5	86.0	14.0
9	391	357	2734	195.5	2538.5	91.3	8.7
10	300	246	3034	150.0	2884.0	82.0	8.0
11	286	255	3320	143.0	3177.0	89.2	10.8
12	381	295	3701	190.5	3510.5	77.4	22.6
13	375	320	4076	187.5	3888.5	85.3	14.7
14	456	384	4532	228.0	4304.0	84.2	15.8
15	386	309	4918	193.0	4725.0	80.1	19.9

SCOTT

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	1238	416	1238	413.0	413.0	33.6	66.4
2	1025	398	2263	512.5	1750.5	38.8	61.2
3	1162	468	3425	581.0	2844.0	40.3	59.7
4	1181	422	4606	590.5	4015.5	35.7	64.3
5	1409	696	6015	704.5	5310.5	49.4	50.6
6	1055	442	7070	527.5	6542.5	41.9	58.1
7	1194	533	8264	597.0	7667.0	44.6	55.4
8	1109	592	9373	554.5	8818.5	53.4	46.6
9	1426	793	10799	713.0	10086.0	55.6	44.4
10	1612	960	12411	806.0	11605.0	59.6	40.4
11	1456	892	13867	728.0	13139.0	61.3	38.7
12	969	615	14836	484.5	14351.5	63.5	36.5
13	1516	962	16352	758.0	15594.0	63.5	36.5
14	1333	810	17685	666.5	17018.5	60.8	39.2
15	1733	1070	19418	866.5	18551.5	61.7	38.3
16	1513	895	20931	756.5	20174.5	59.2	40.8

SHEPPARD

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	799	309	799	266.0	266.0	38.7	61.3
2	896	334	1695	448.0	1247.0	37.3	62.7
3	978	362	2673	489.0	2184.0	37.0	63.0
4	1080	423	3753	540.0	3213.0	39.2	60.8
5	836	367	4589	418.0	4171.0	43.9	36.1
6	975	443	5564	487.5	5076.5	45.4	34.6
7	703	414	6267	351.5	5915.5	58.9	41.1
8	763	529	7030	381.5	6648.5	69.3	30.7
9	754	477	7784	377.0	7407.0	63.3	36.7
10	1012	714	8796	506.0	8290.0	70.6	29.4
11	831	529	9627	415.5	9211.5	63.7	36.3
12	426	302	10053	213.0	9840.0	70.9	29.1
13	784	553	10837	392.0	10445.0	70.5	29.5
14	843	613	11680	421.5	11258.5	72.7	27.3
15	899	659	12579	449.5	12129.5	73.3	26.7
16	801	651	13380	400.5	12979.5	81.3	18.7

VANDENBERG

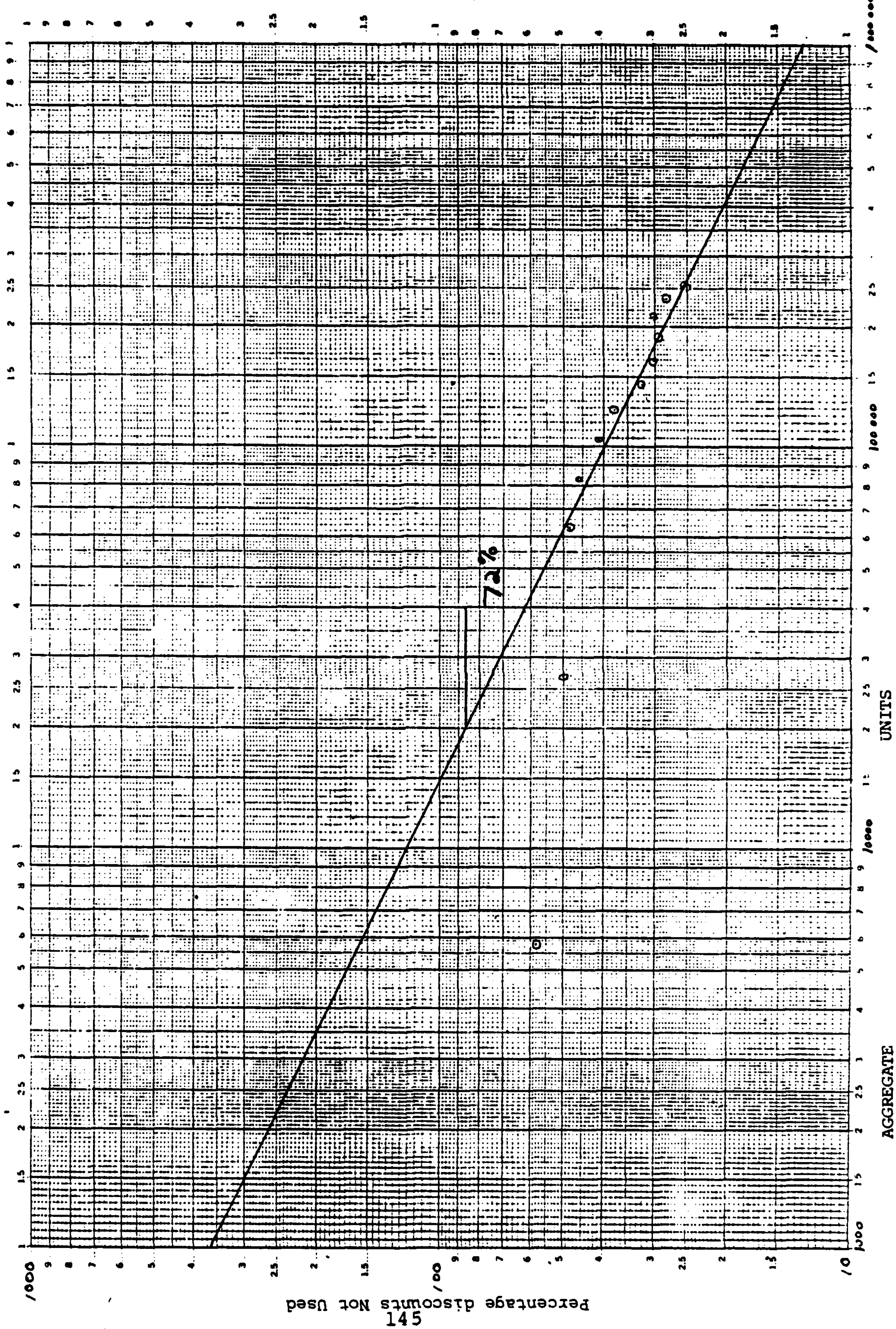
Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	203	78	203	68.0	68.0	38.4	61.6
2	271	102	474	135.5	338.5	37.6	62.4
3	242	127	716	121.0	595.0	52.5	47.5
4	282	156	998	141.0	857.0	55.3	44.7
5	284	152	1282	142.0	1140.0	53.5	46.5
6	297	204	1579	148.5	1430.5	68.7	31.3
7	311	224	1890	155.5	1734.5	72.0	28.0
8	305	227	2195	152.5	2042.5	74.4	25.6
9	363	286	2558	181.5	2376.5	78.8	21.2
10	334	169	2892	167.0	2725.0	50.6	27.8
11	222	175	3114	111.0	3003.0	78.8	21.2
12	351	283	3465	175.5	3289.5	80.6	19.4
13	313	248	3778	156.5	3621.5	79.2	20.8
14	401	337	4179	200.5	3978.5	84.0	16.0
15	407	281	4586	203.5	4382.5	69.0	31.0

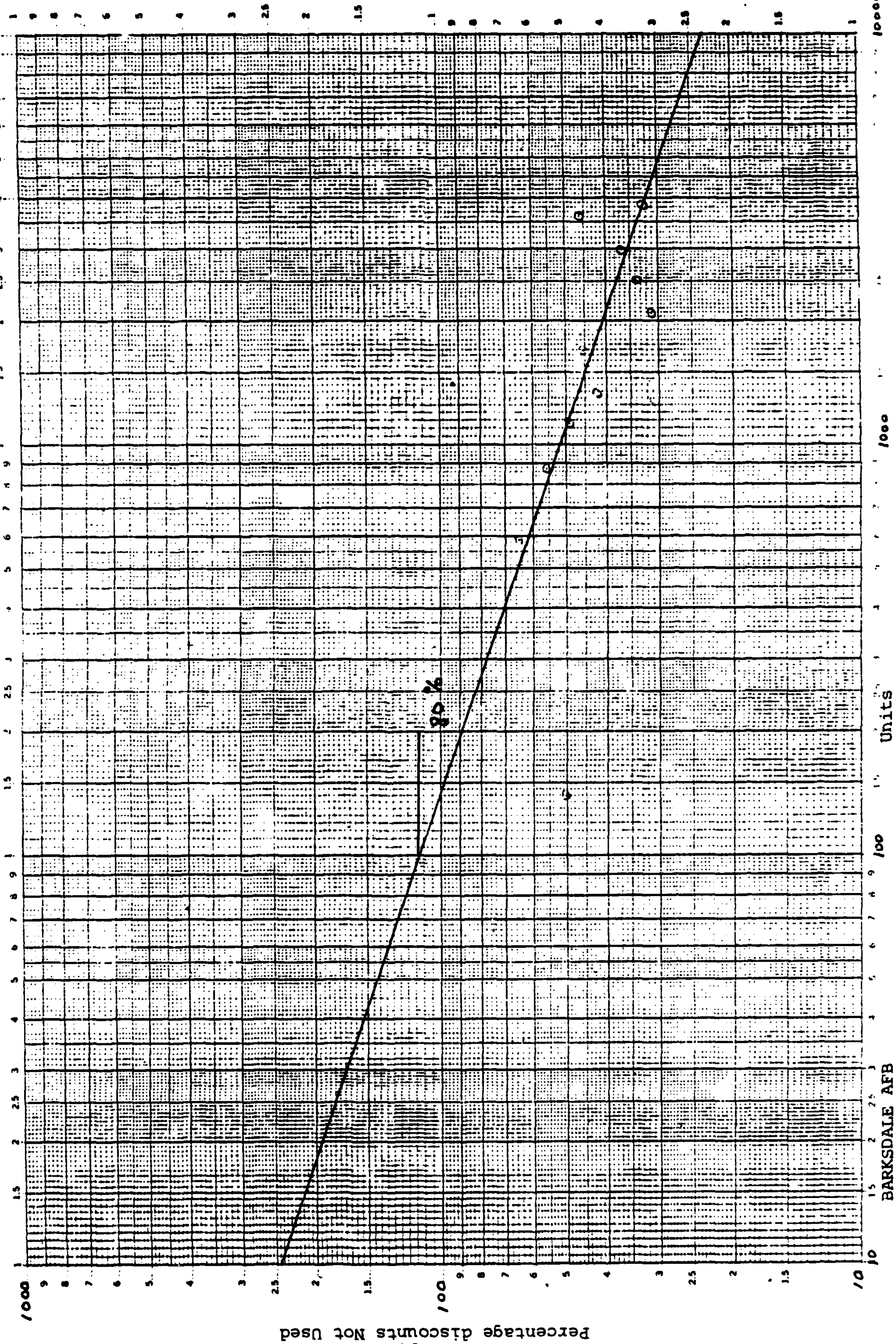
WRIGHT-PATTERSON

Month (1)	Number of Passengers (2)	Number of Discounts (3)	Cumulative Number of Passengers (4)	Monthly Midpoint (5)	PPx (6)	Discount Usage Rate (7)	PPy (8)
1	4881	1145	4881	1627.0	1627.0	23.5	76.5
2	4082	1165	8963	2041.0	6922.0	28.5	71.5
3	4332	1392	13295	2166.0	11129.0	32.1	67.9
4	4389	1500	17684	2194.5	15489.5	34.2	65.8
5	4403	1716	22087	2201.5	19885.5	39.0	61.0
6	4304	1931	26391	2152.0	24239.0	44.9	55.1
7	4434	2255	30825	2217.0	28608.0	50.9	49.1
8	3992	1820	34817	1996.0	32821.0	45.6	54.4
9	5016	2437	39833	2508.0	37325.0	48.6	51.4
10	6009	2959	45842	3004.5	42837.5	49.2	50.8
11	4670	2362	50512	2335.0	48177.0	50.6	49.4
12	3359	1588	53871	1679.5	52191.5	47.3	52.7
13	5404	3280	59275	2702.0	56573.0	60.7	39.3
14	4673	2650	63948	2336.5	61611.5	56.7	43.3
15	5358	3047	69306	2679.0	66627.0	56.9	43.1
16	5343	3135	74649	2671.5	71977.5	58.7	41.3

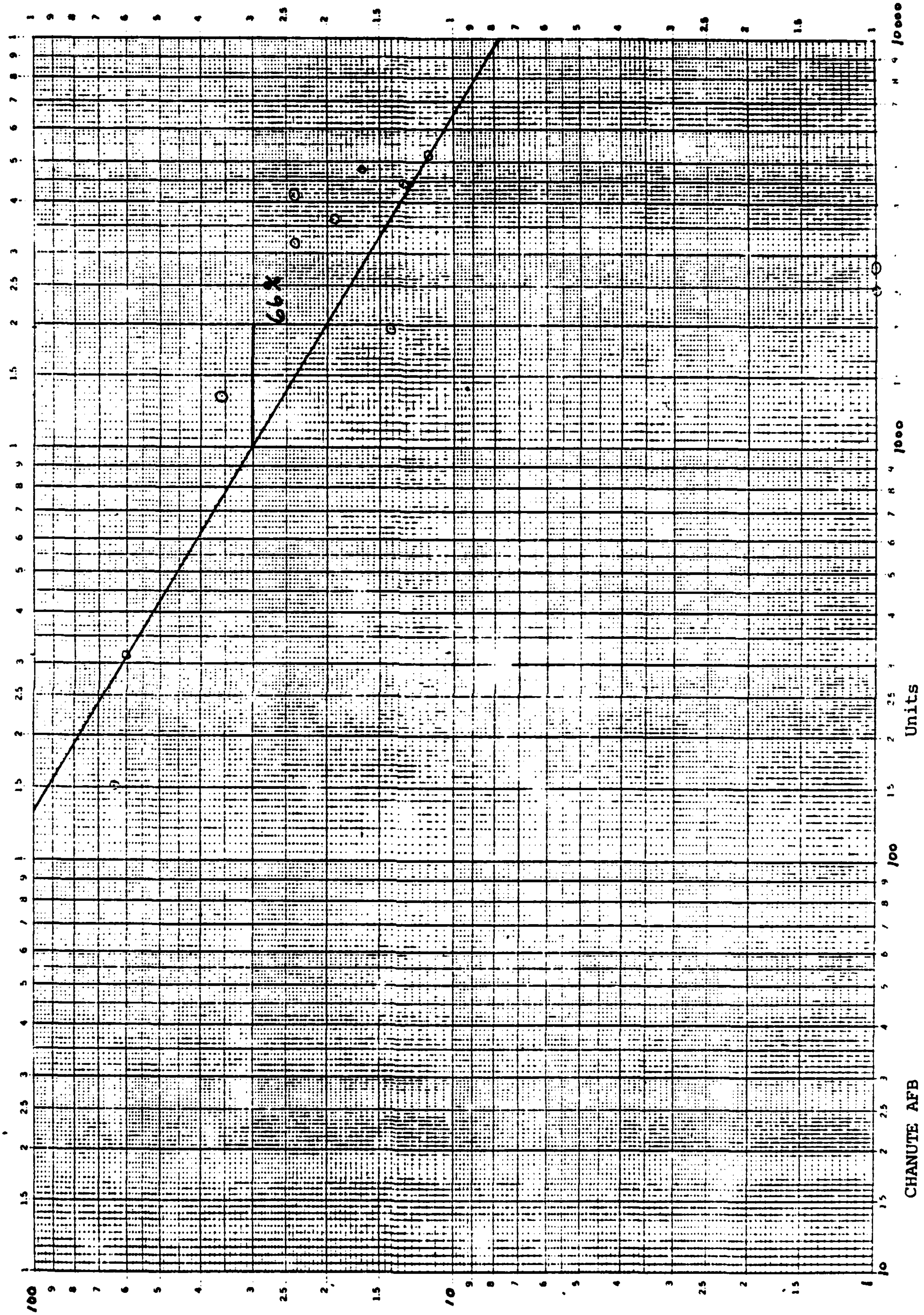
APPENDIX D

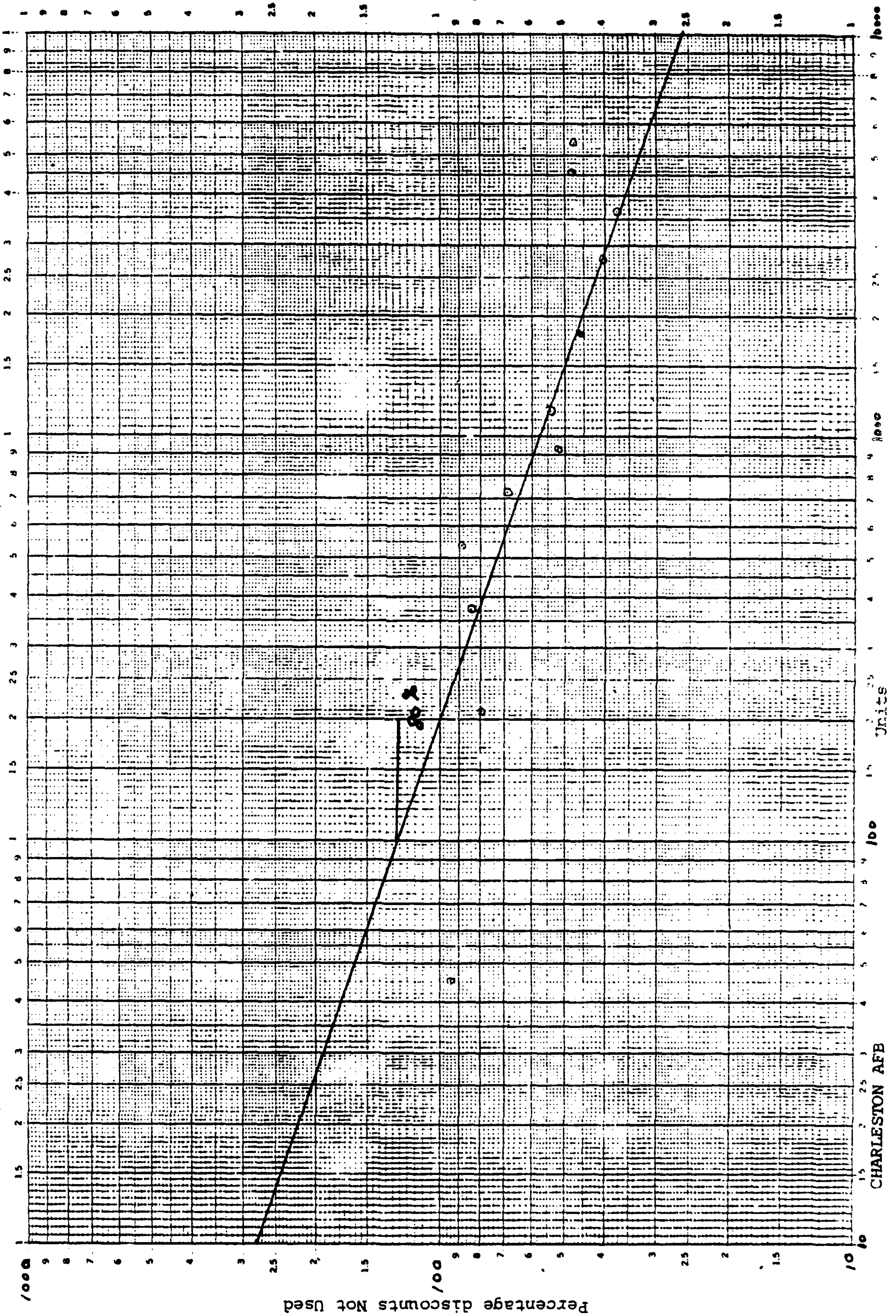
LEARNING CURVE GRAPHS FOR EACH SAMPLE BASE
AND THE AGGREGATE ON LOG-LOG PAPER

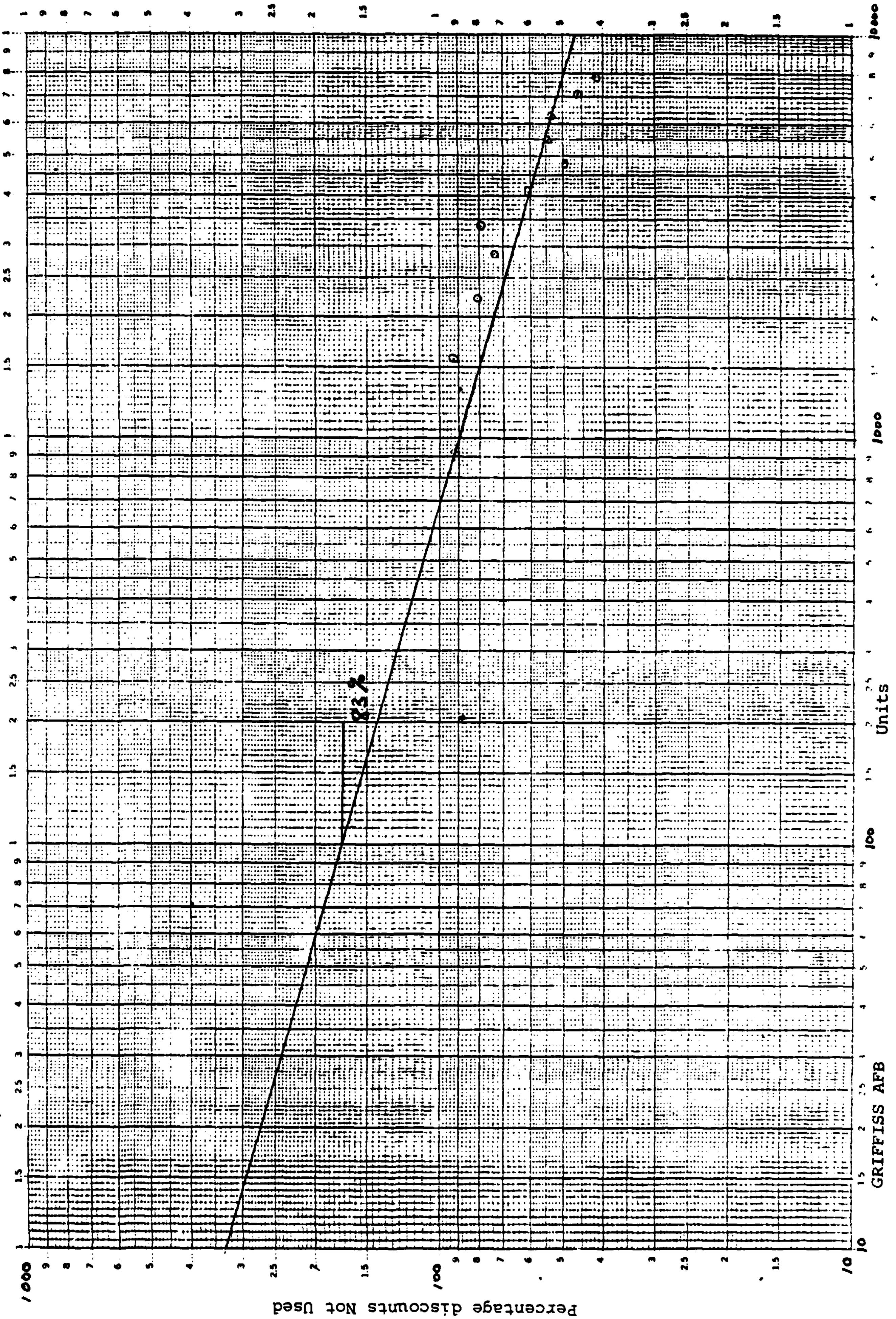

72%
AGGREGATE UNITS
Percentage discounts Not Used

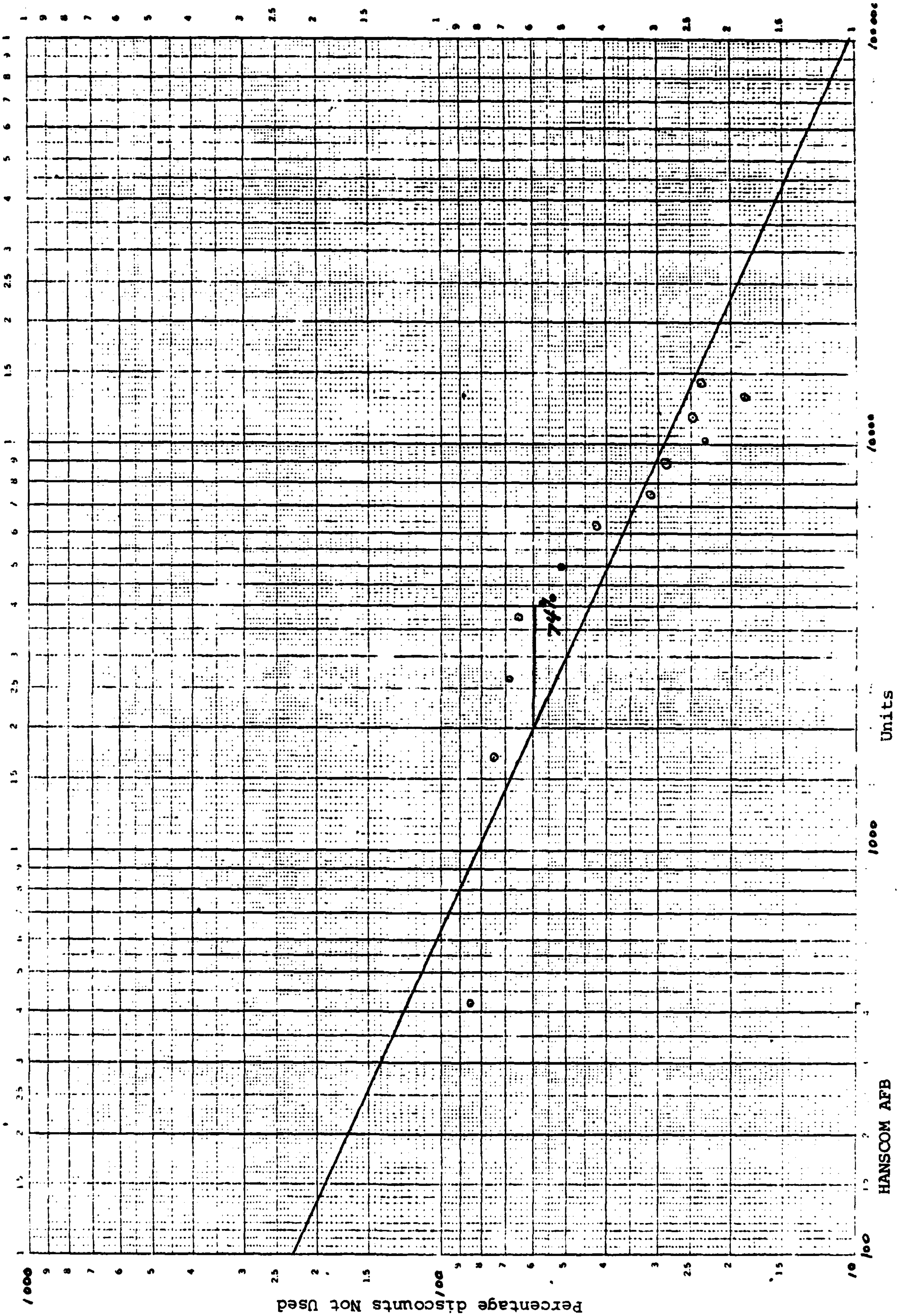


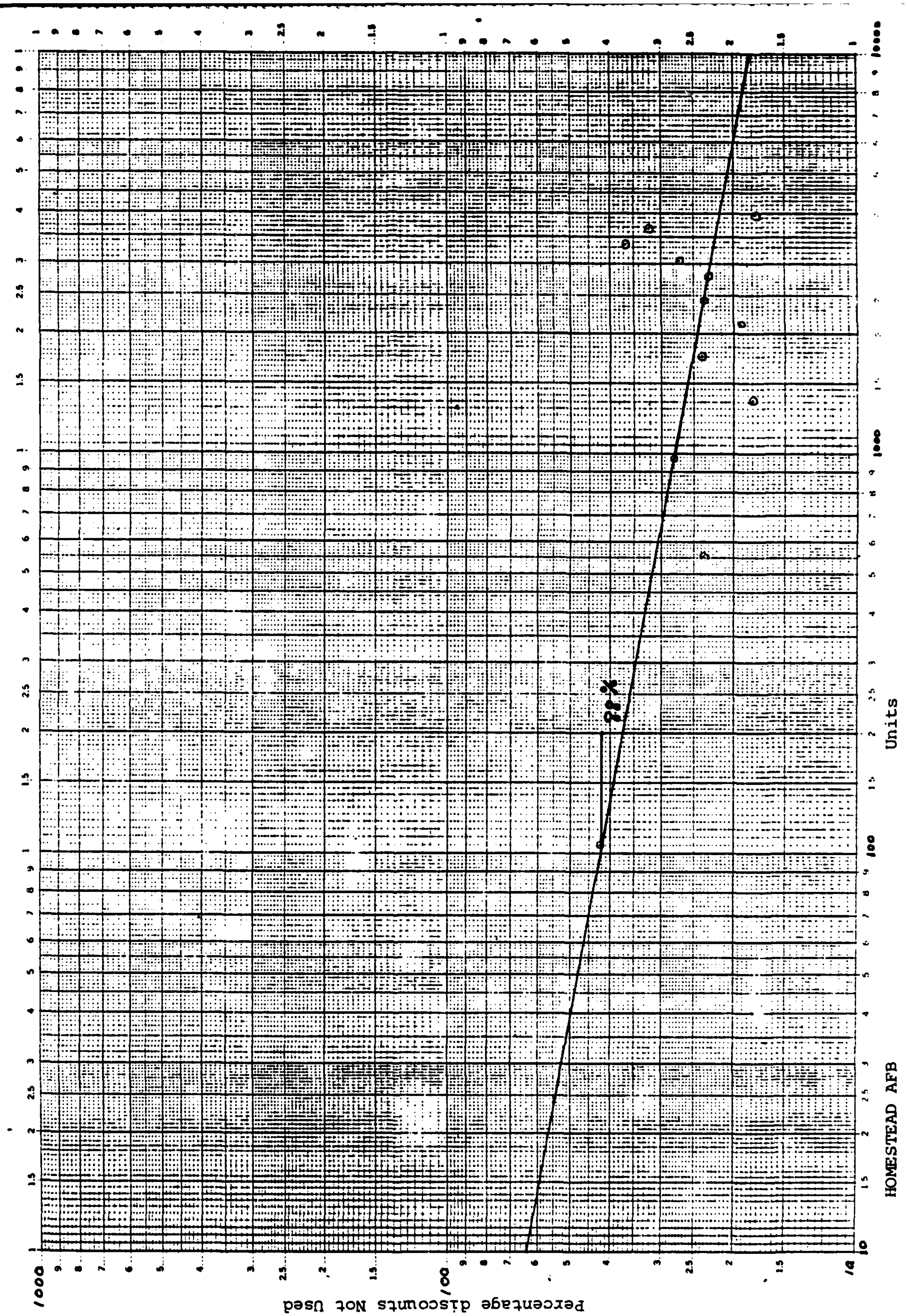
80%
Units
BARKSDALE AFB
Percentage discounts Not Used

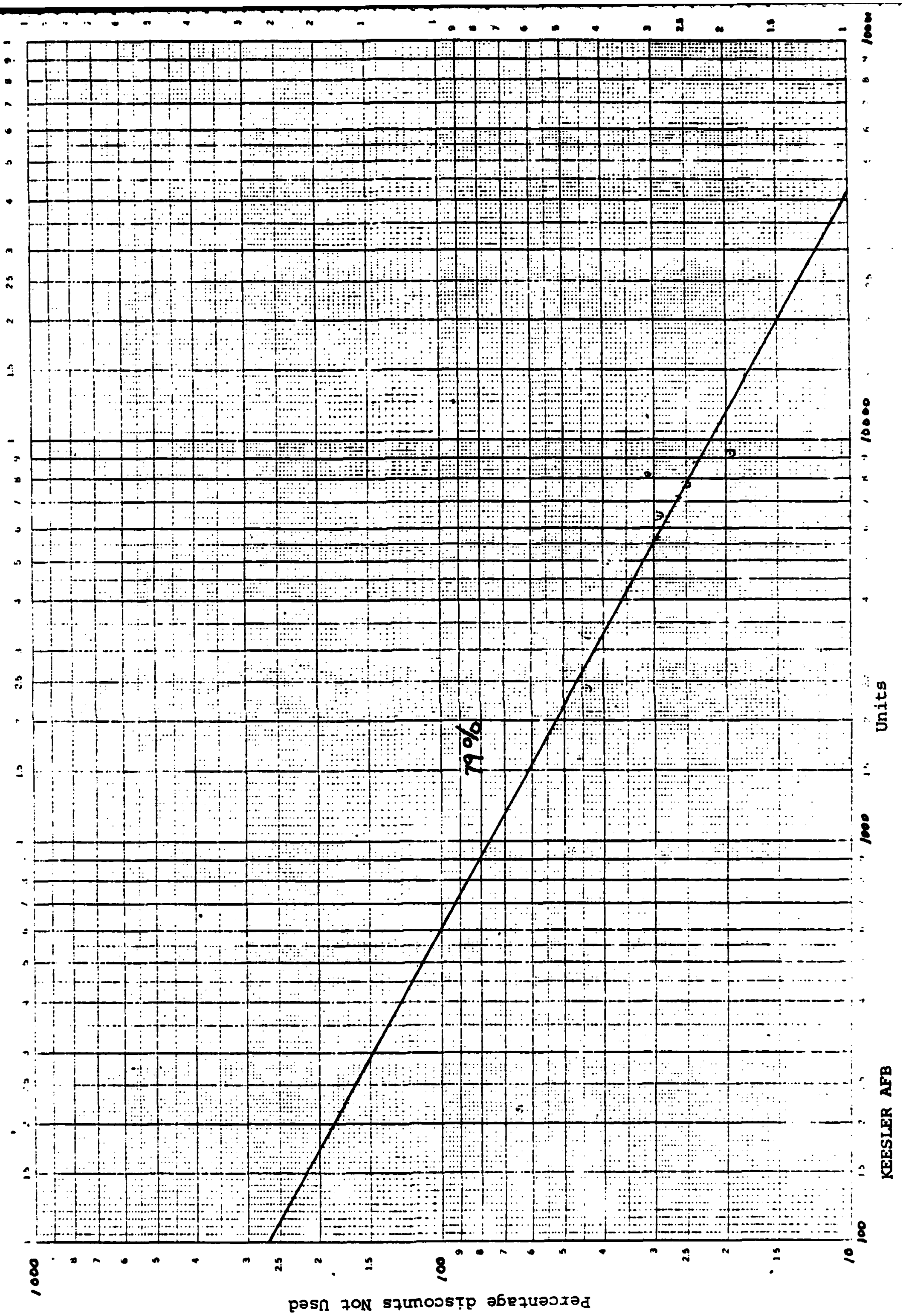

CHANUTE AFB
Units
Percentage discounts Not Used
10
100
1000
10000

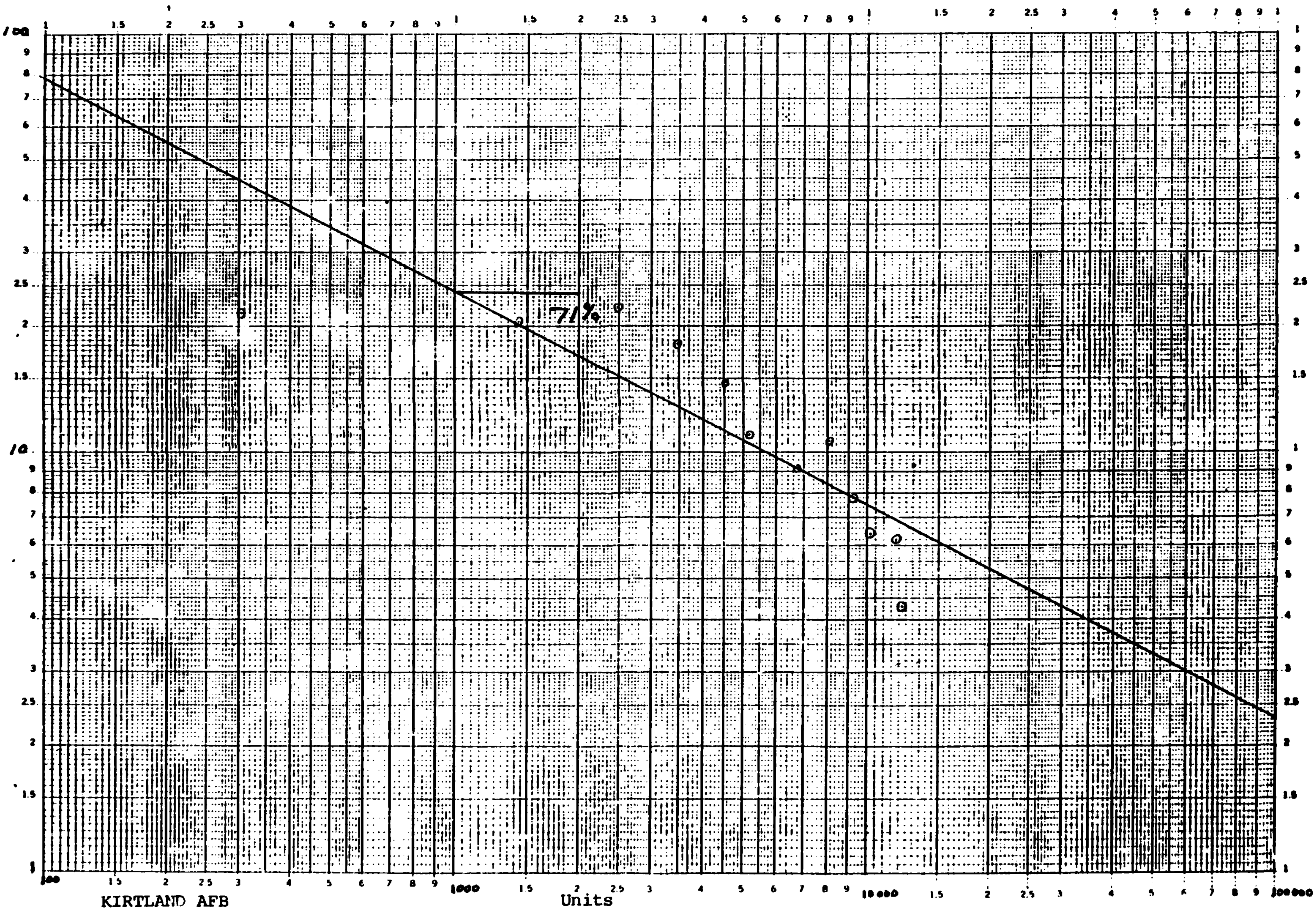

CHARLESTON AFB
Units
Percentage discounts Not Used


83%
Units
GRIFFISS AFB
Percentage discounts Not Used
10
100
1000
10000

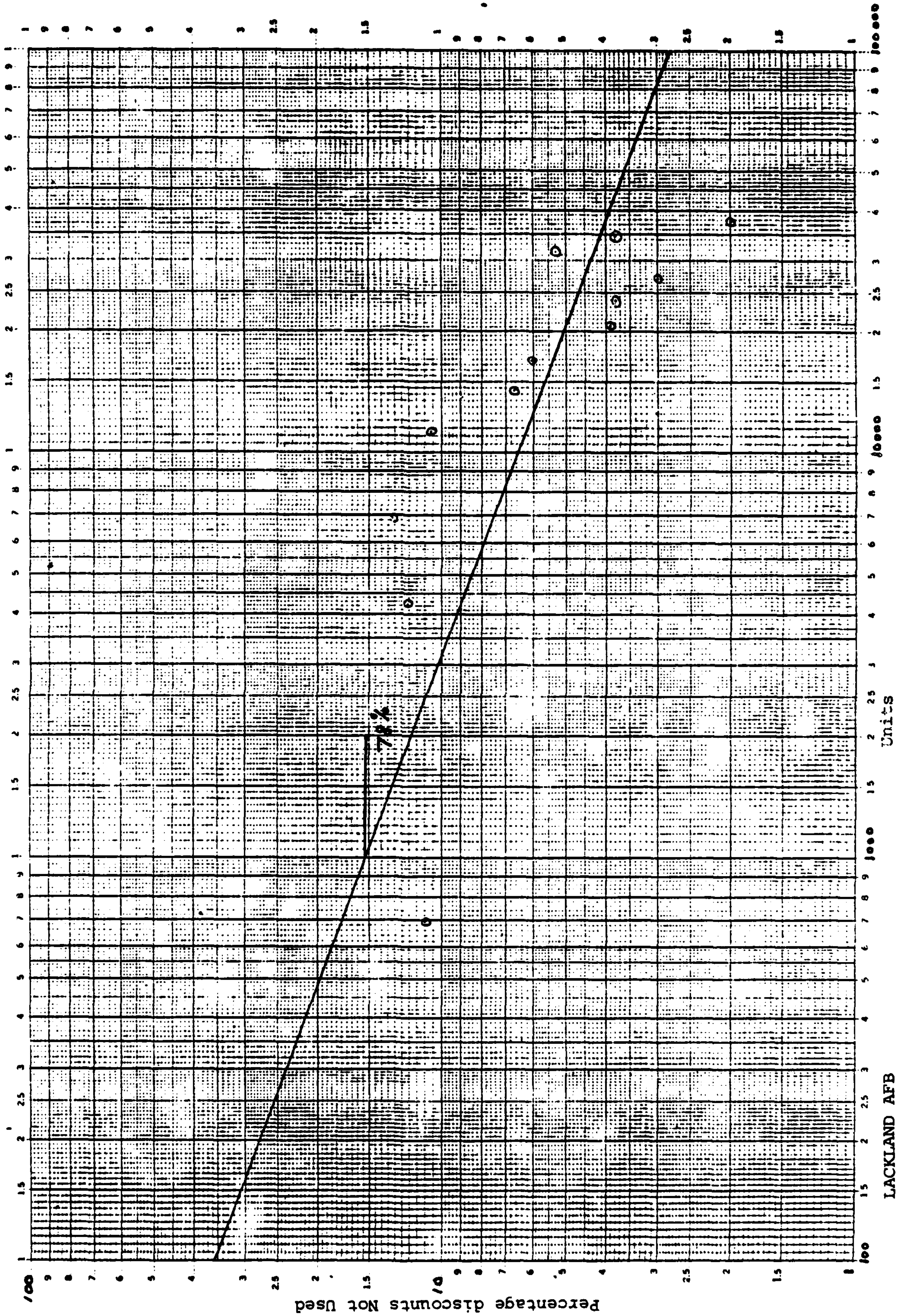

HANSCOM AFB
Units
Percentage discounts Not Used
74%


HOMESTEAD AFB
Units
Percentage discounts Not Used
28%

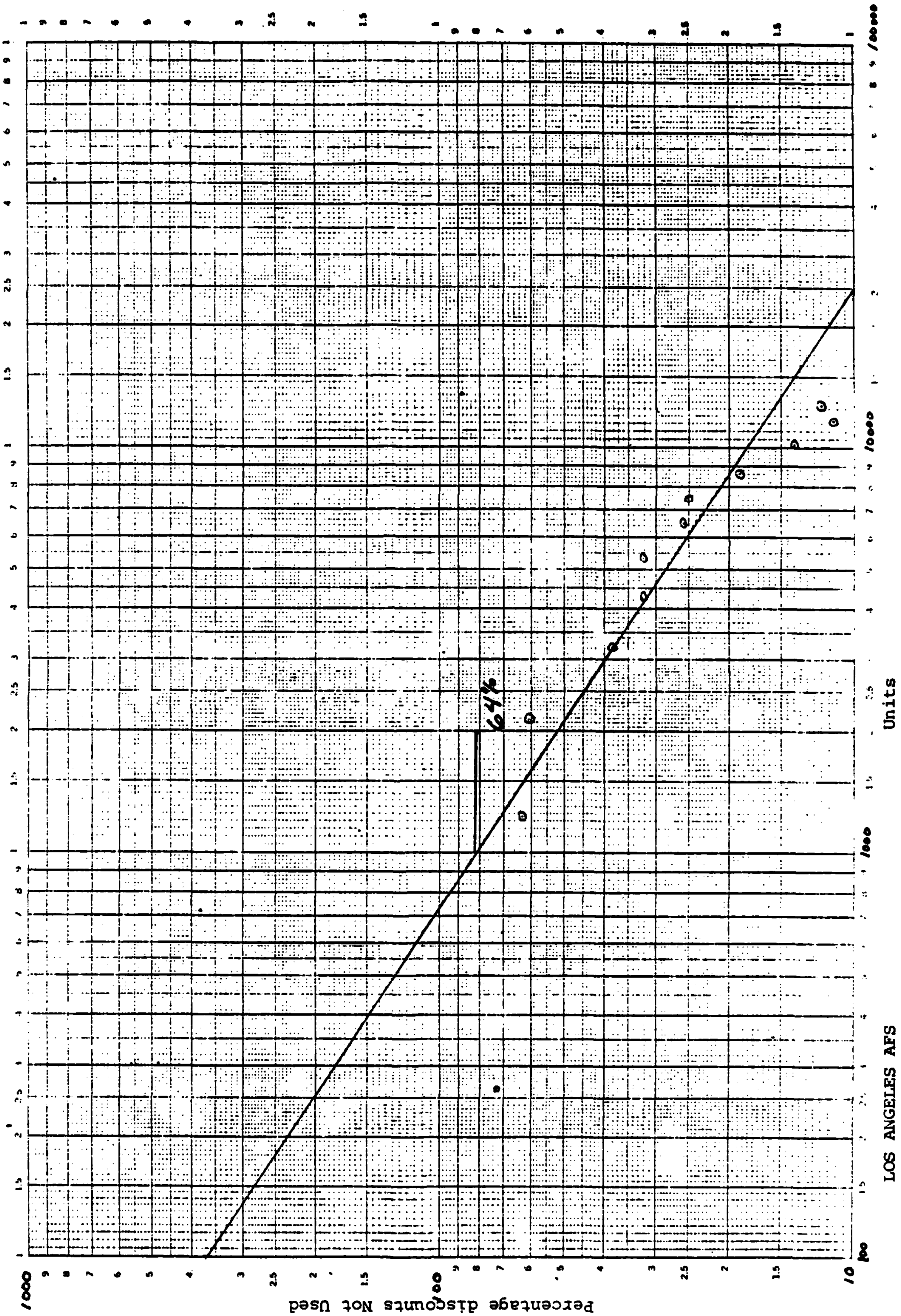

79%
Units
KEESLER AFB
Percentage discounts Not Used

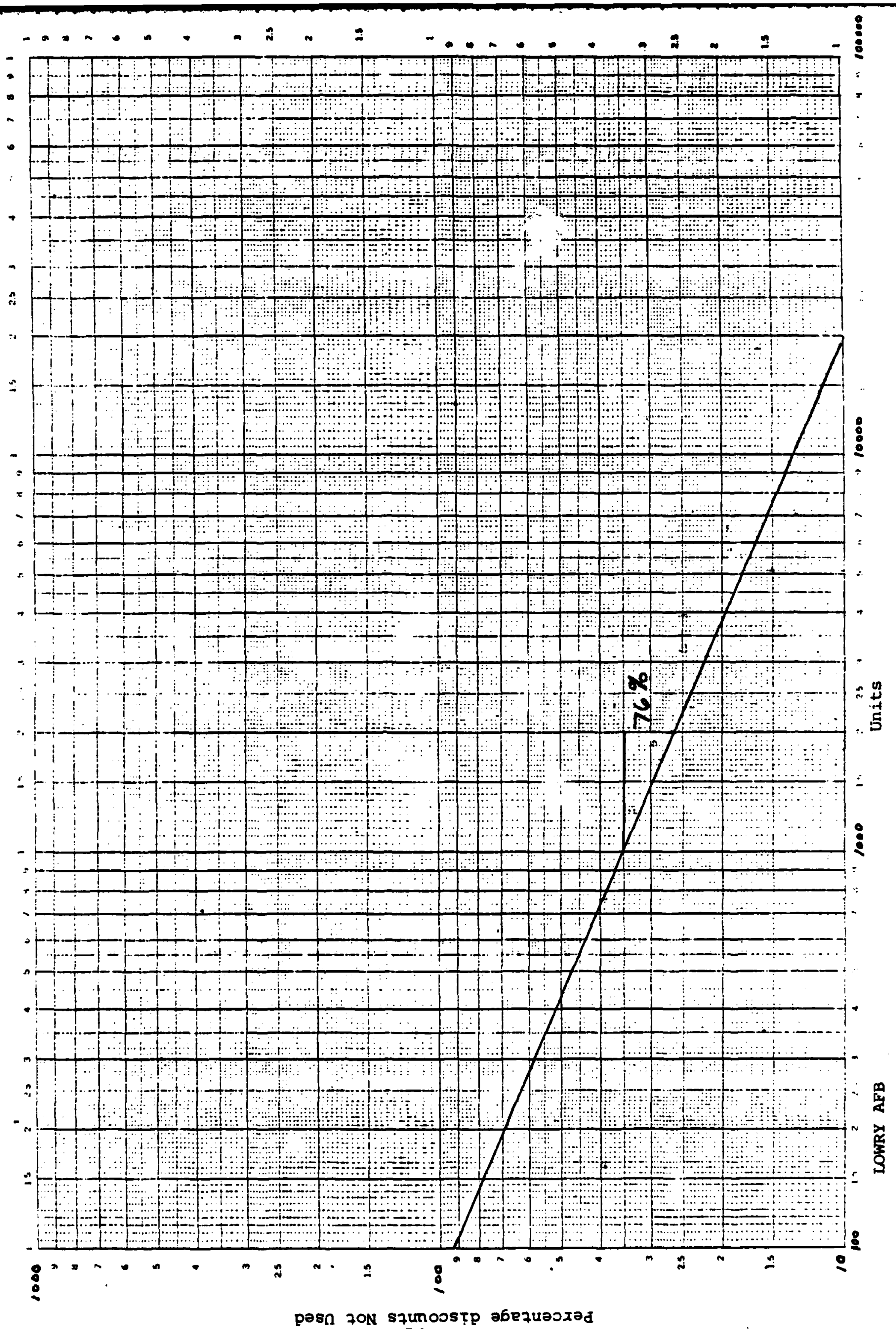


Percentage discounts Not Used
71%
KIRTLAND AFB
Units

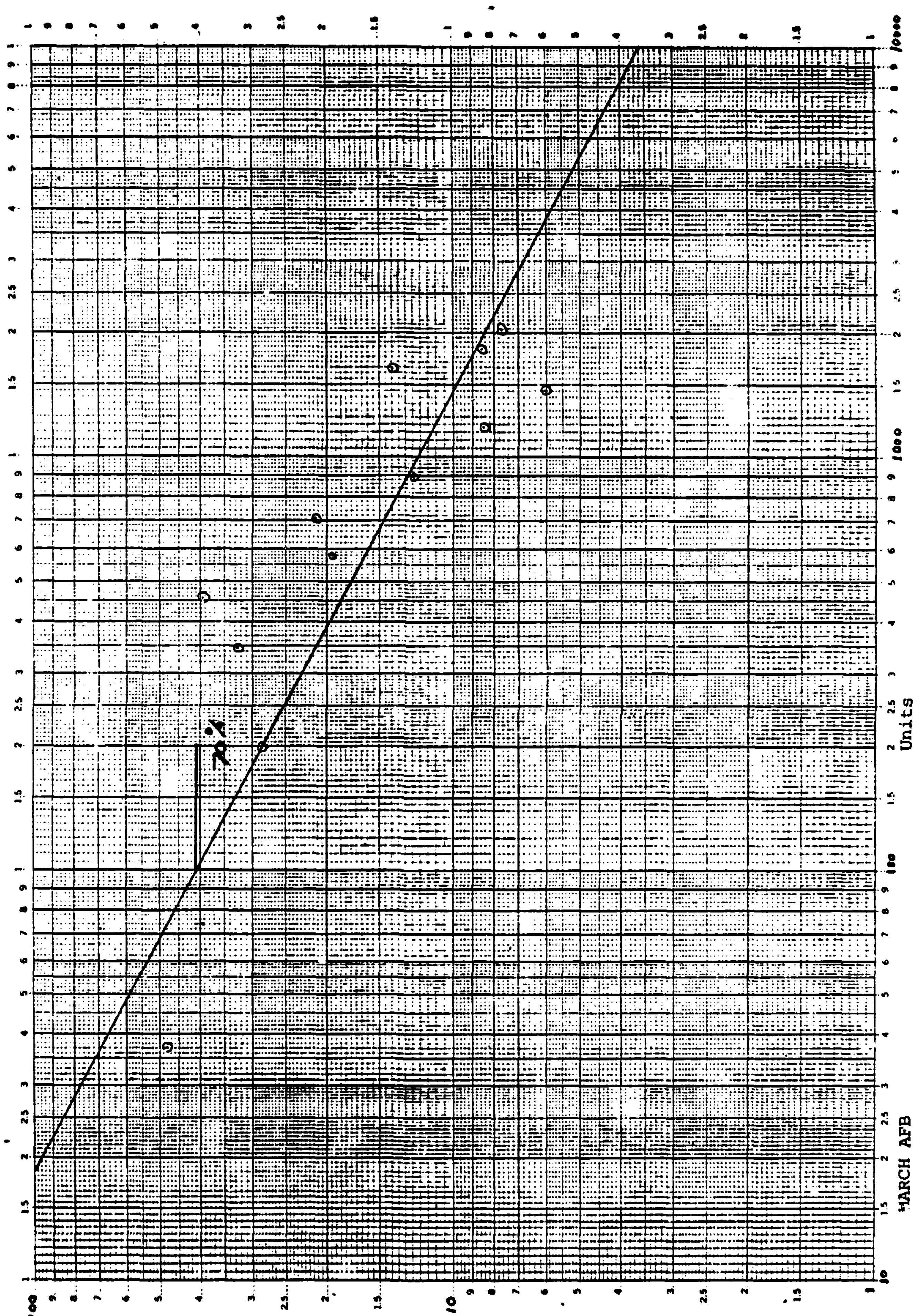


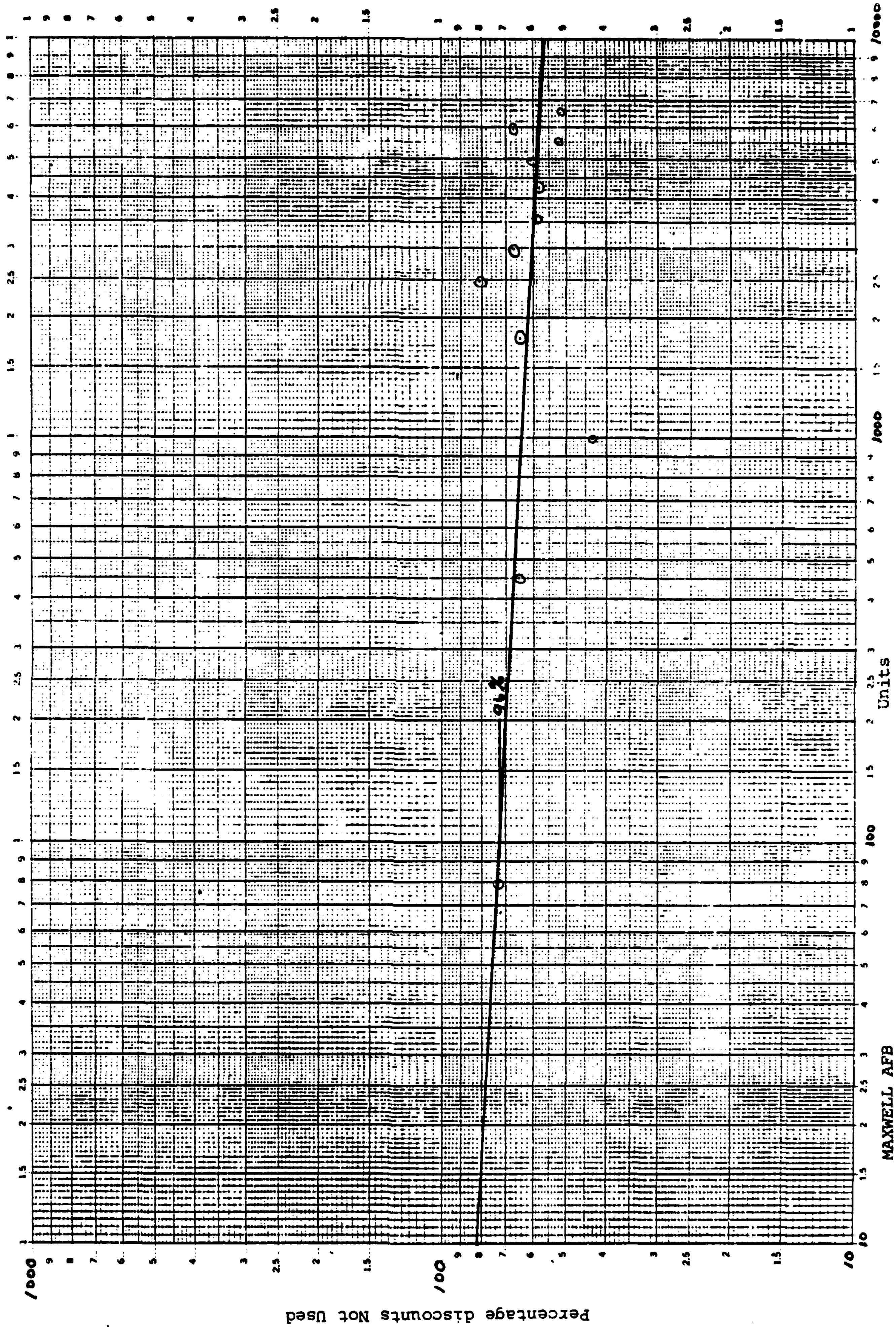
78%
Units
LACKLAND AFB
Percentage discounts Not Used

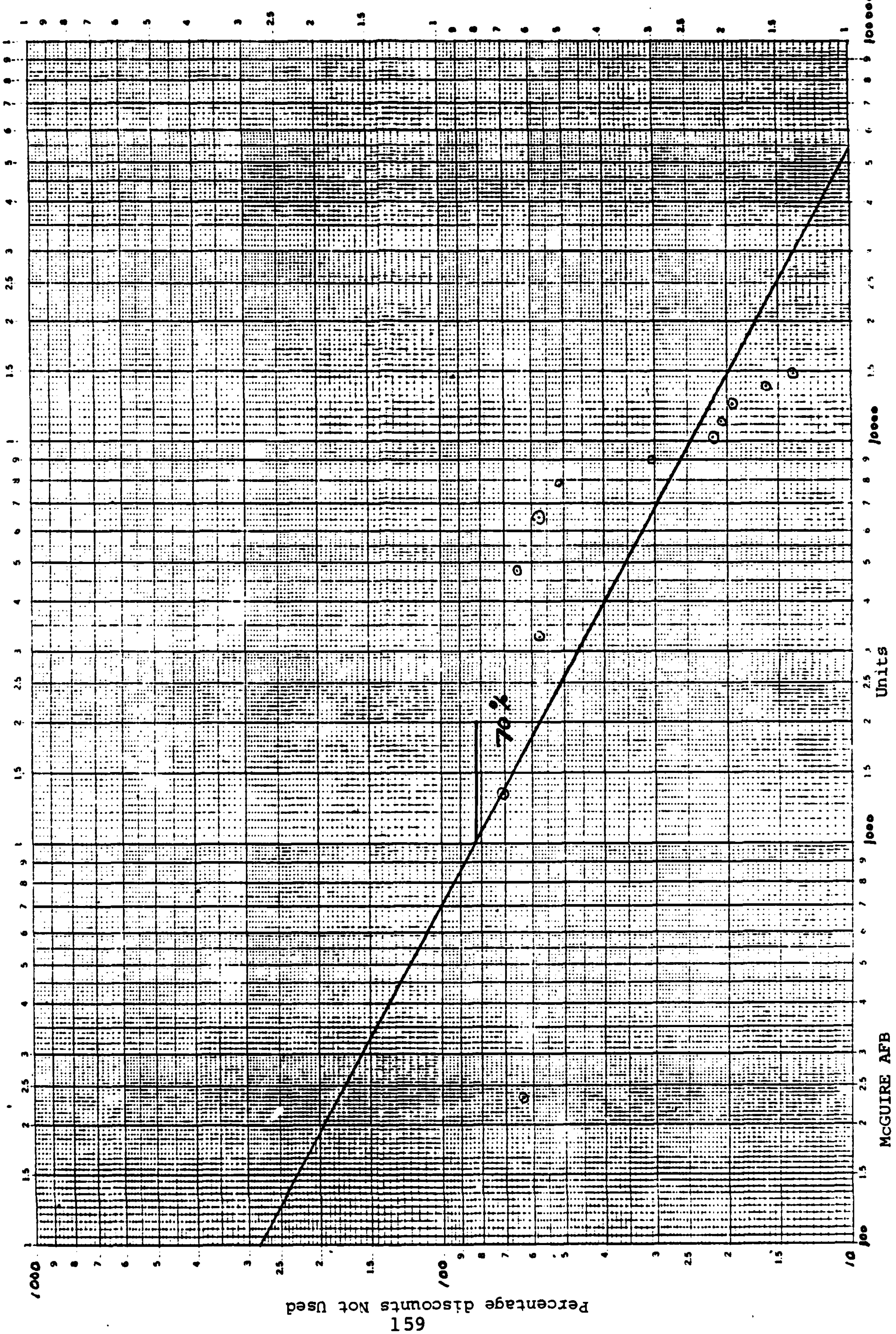

64%
Units
LOS ANGELES AFS
Percentage discounts Not Used

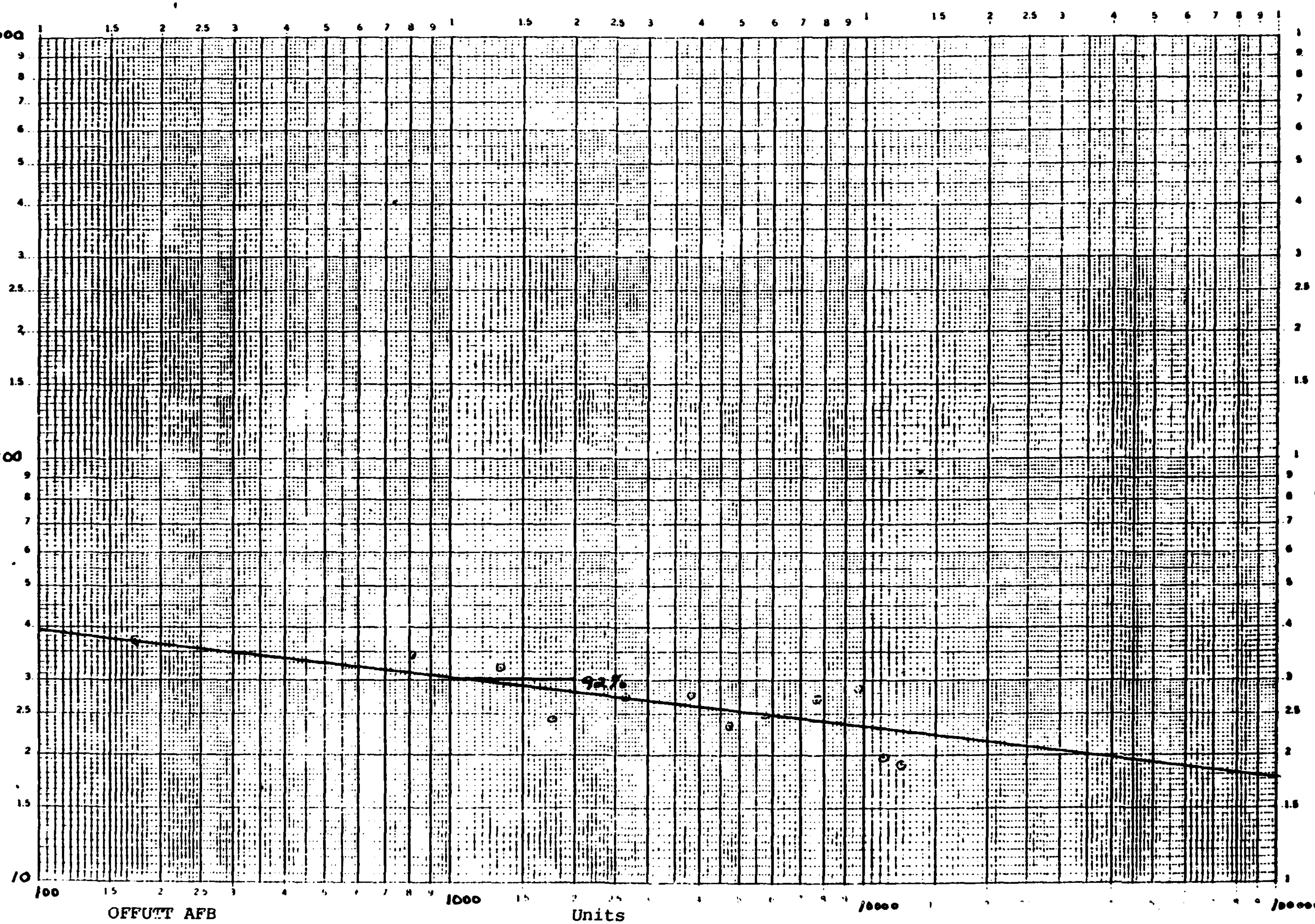


76%
Units
LOWRY AFB
Percentage discounts Not Used

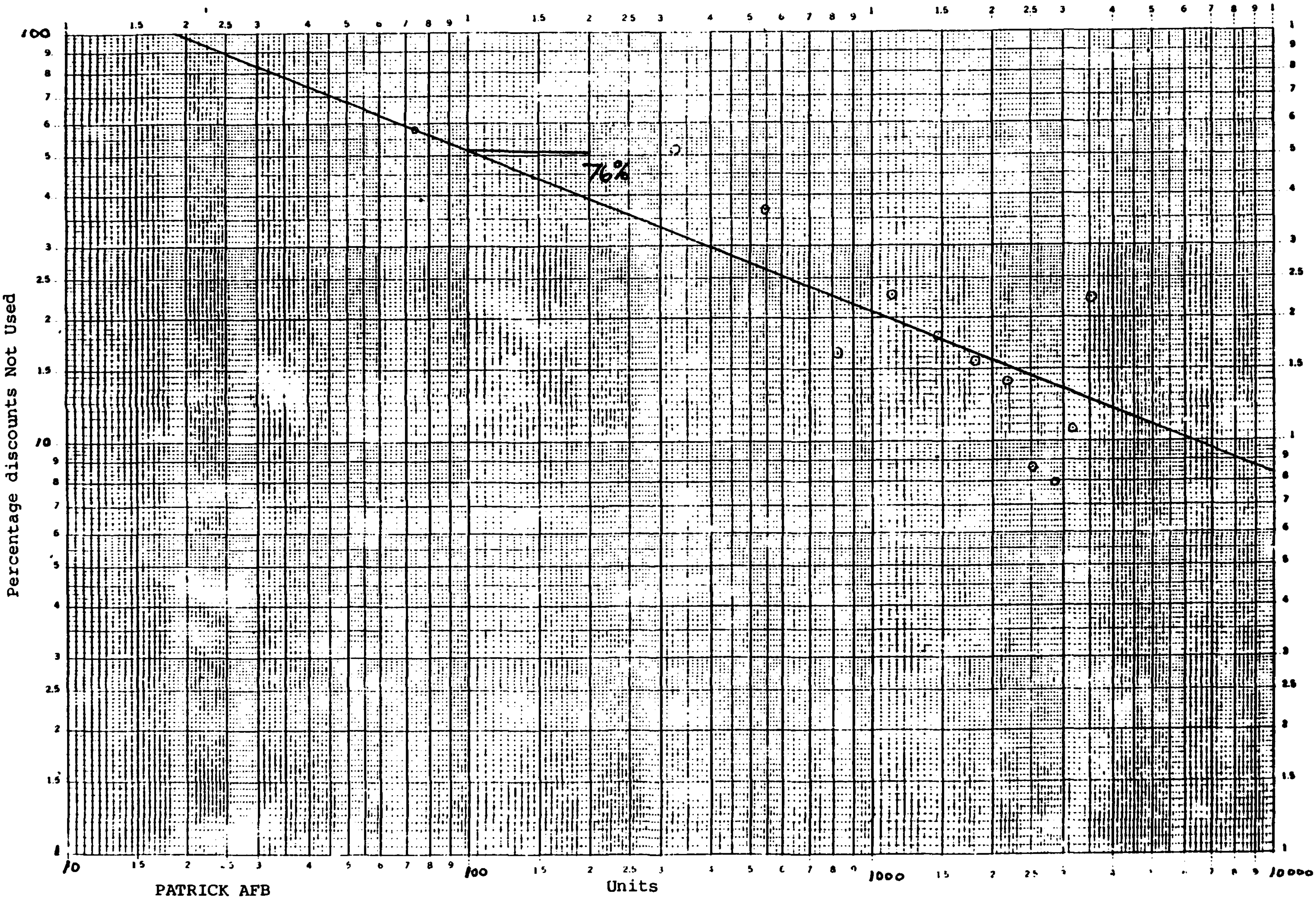

Units
MARCH AFB
Percentage discounts Not Used
20%


Units
MAXWELL AFB
Percentage discounts Not Used

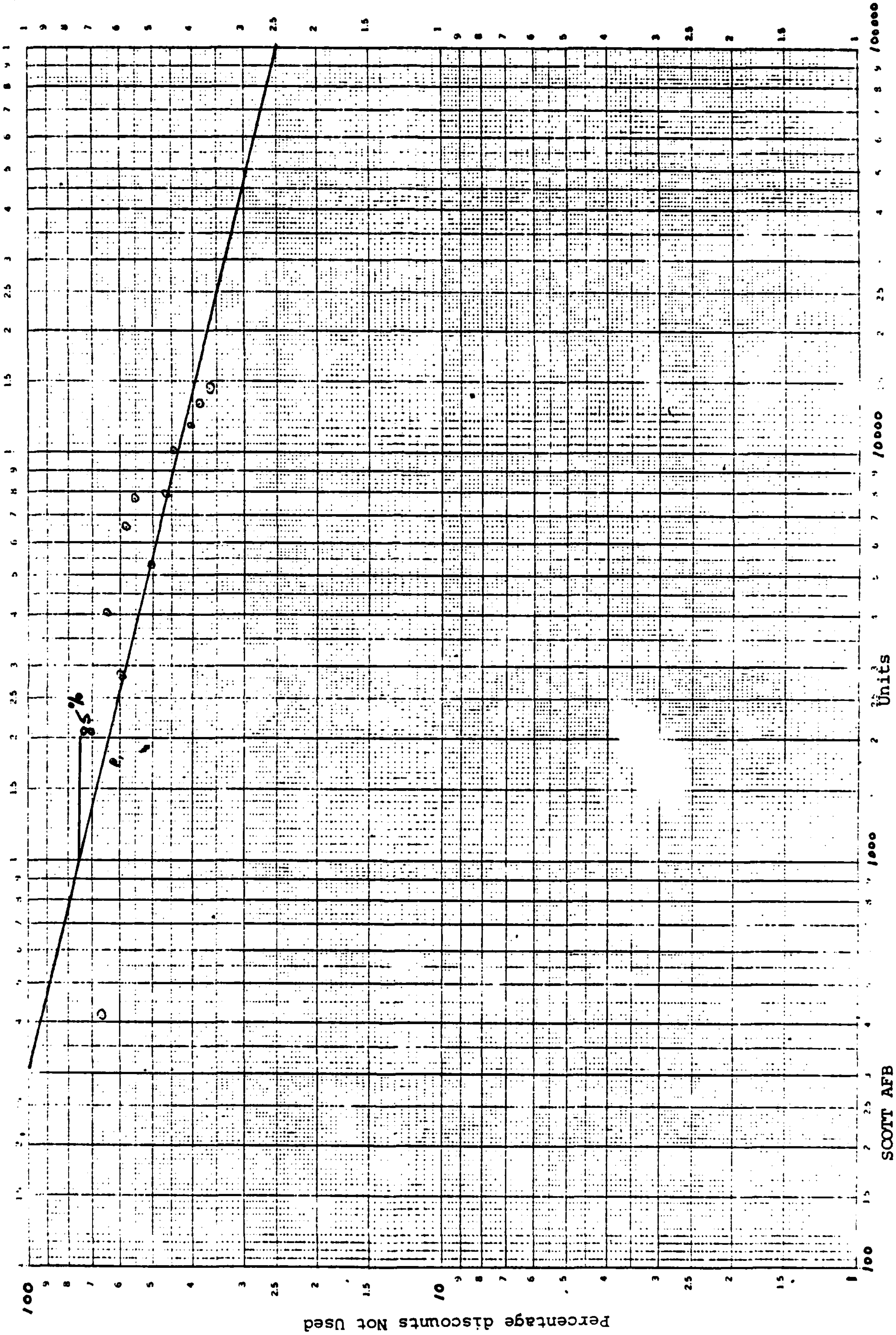

70%
Units
McGUIRE AFB
Percentage discounts Not Used



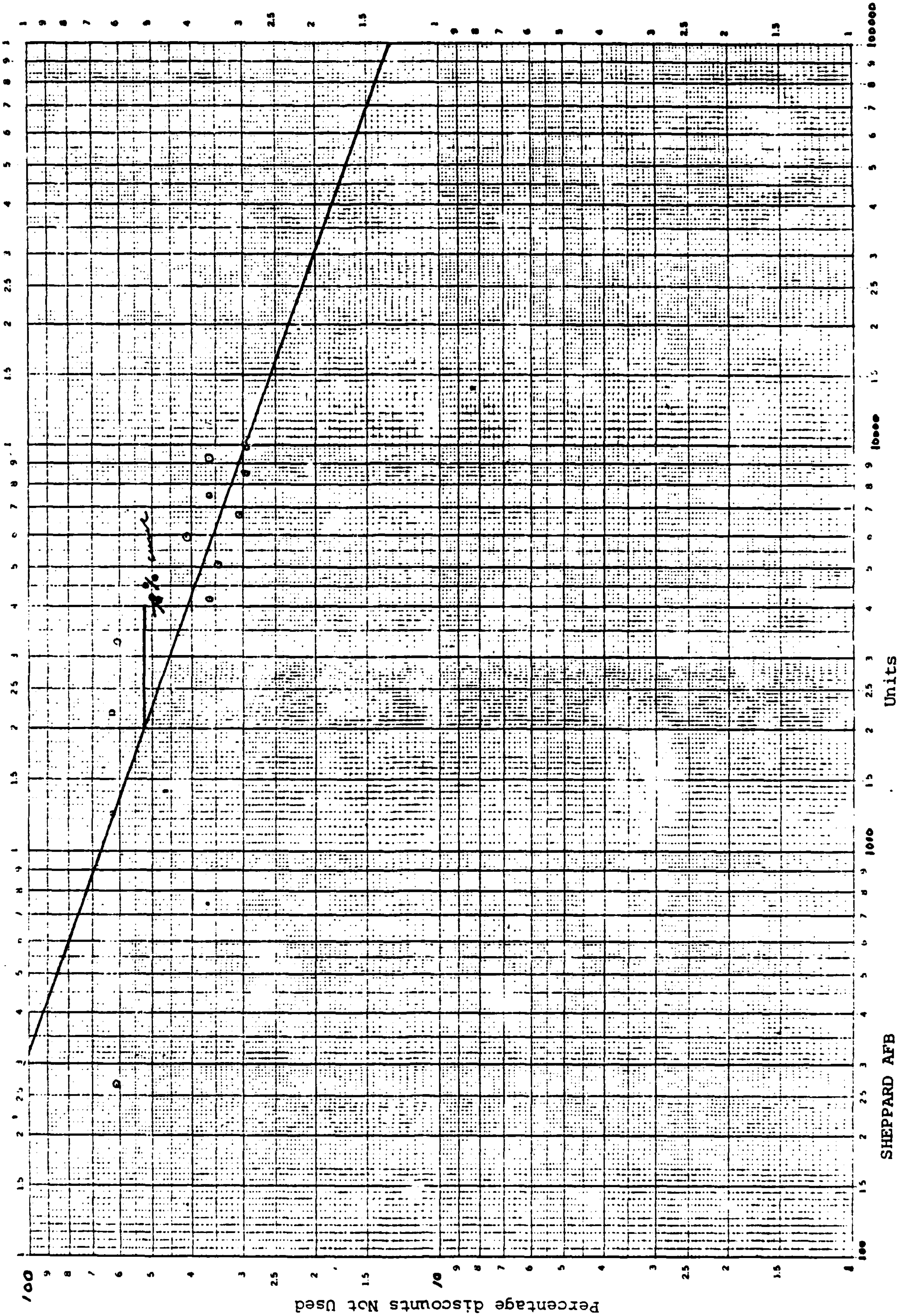
1000
100
10
100
1000
10000
100000
92%
OFFUTT AFB
Units
Percentage discounts Not Used

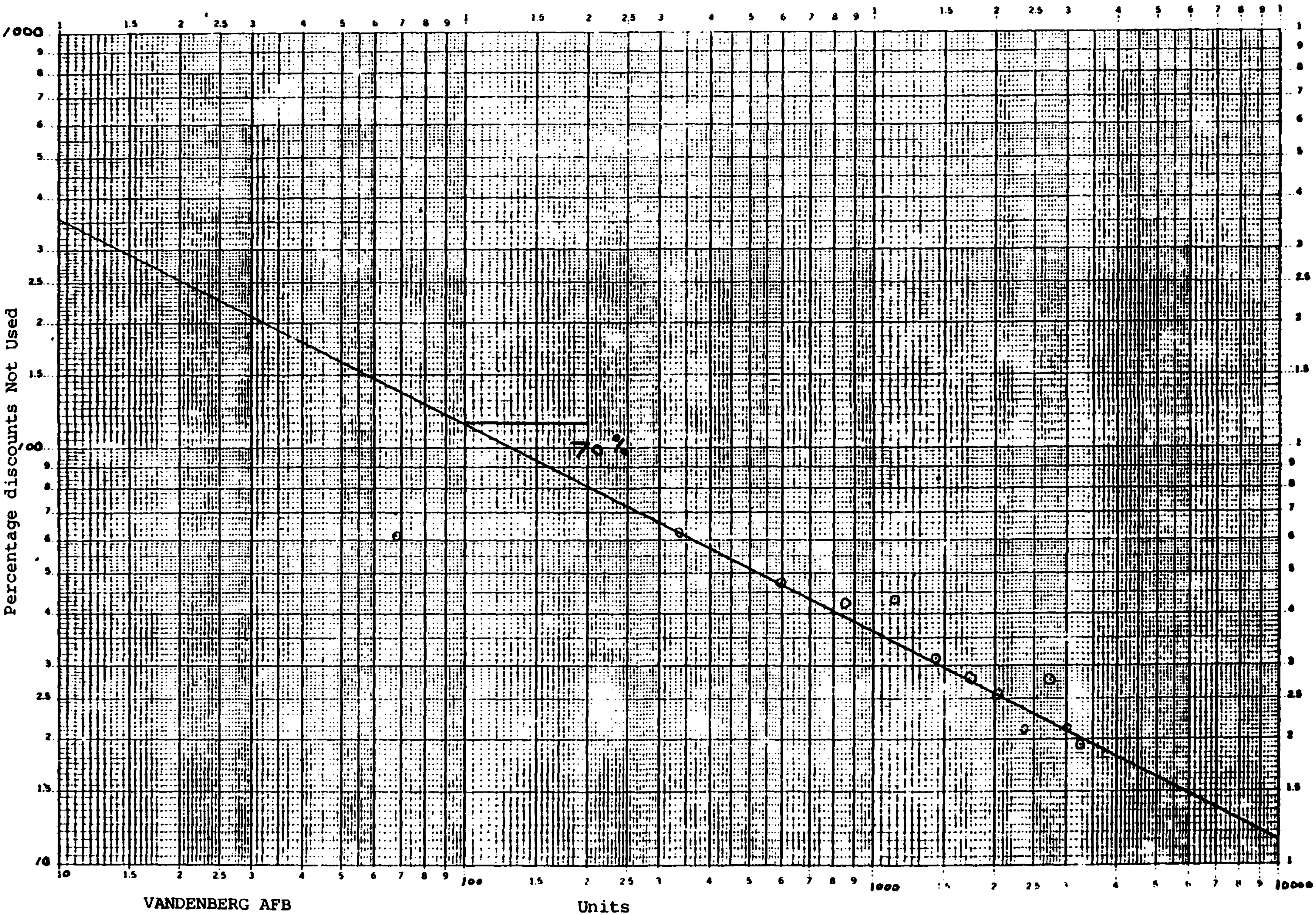


Percentage discounts Not Used
Units
76%
PATRICK AFB

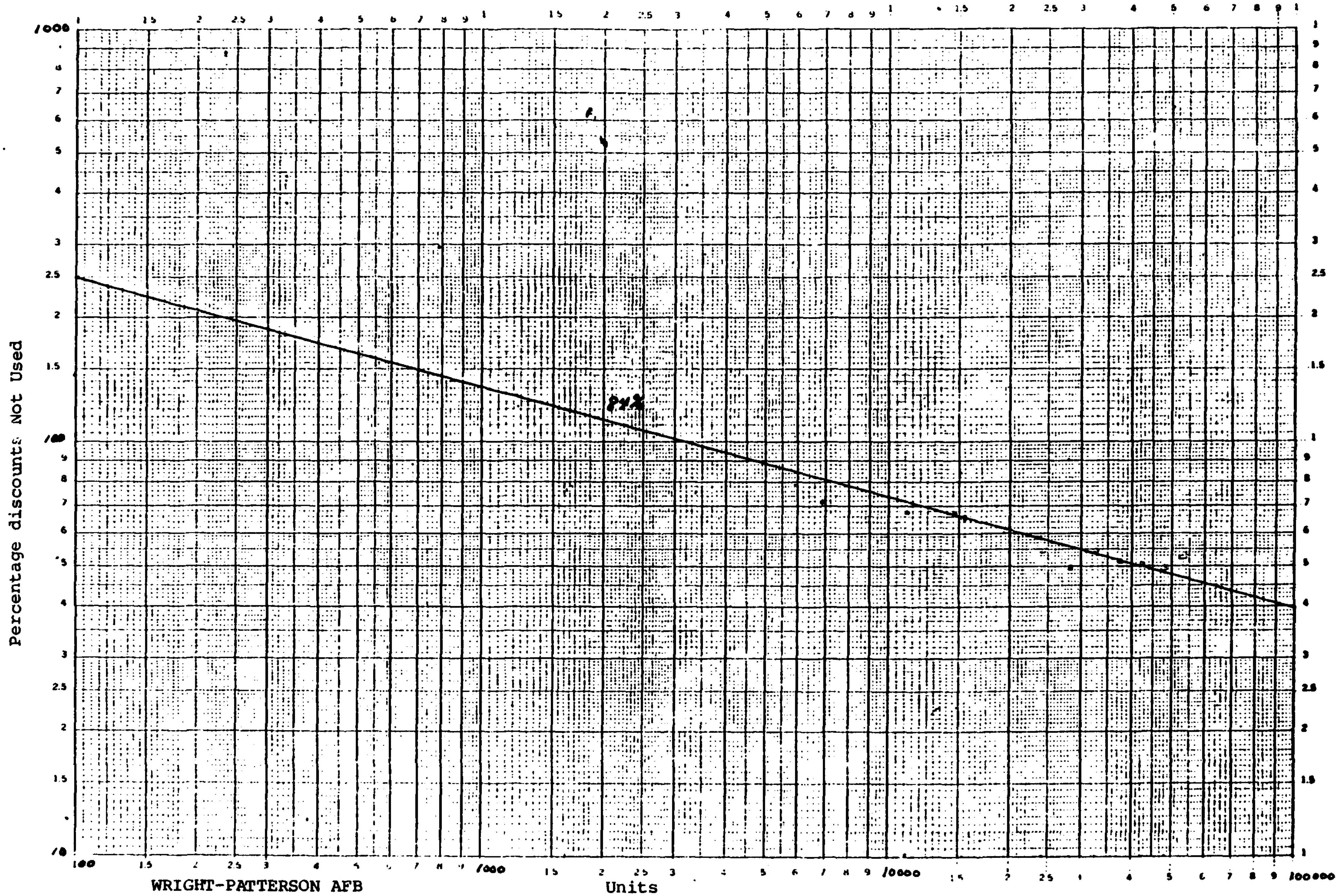


SCOTT AFB
Units
100
1000
10000
100000
Percentage discounts Not Used
100
10
1
85%


Units
SHEPPARD AFB
Percentage discounts Not Used



VANDENBERG AFB


Percentage discounts Not Used
84%
WRIGHT-PATTERSON AFB
Units

APPENDIX E

LEARNING CURVE GRAPHS FOR EACH SAMPLE BASE AND THE AGGREGATE BY THE 4051 TEKTRONIX SIMPLE LINEAR REGRESSION PACKAGE

Y = A*X↑B

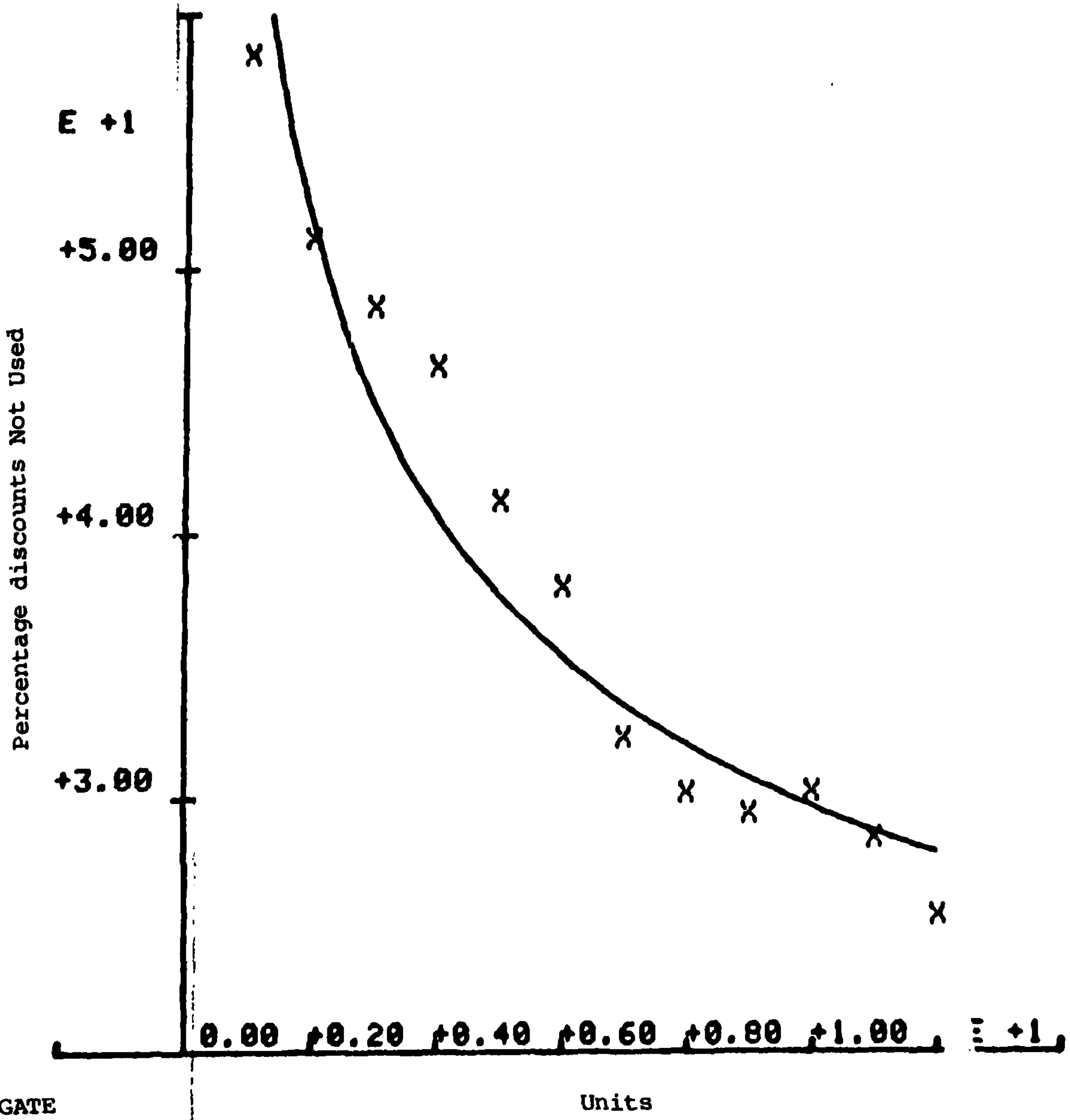
A =
65.7045332093

B =
-0.346464242409

R-SQUARE =
0.895790775715

RES ERROR
13.1289033307

MAX(ABS(RESIDUAL))
7.40453320933



AGGREGATE

Y = A*X↑B

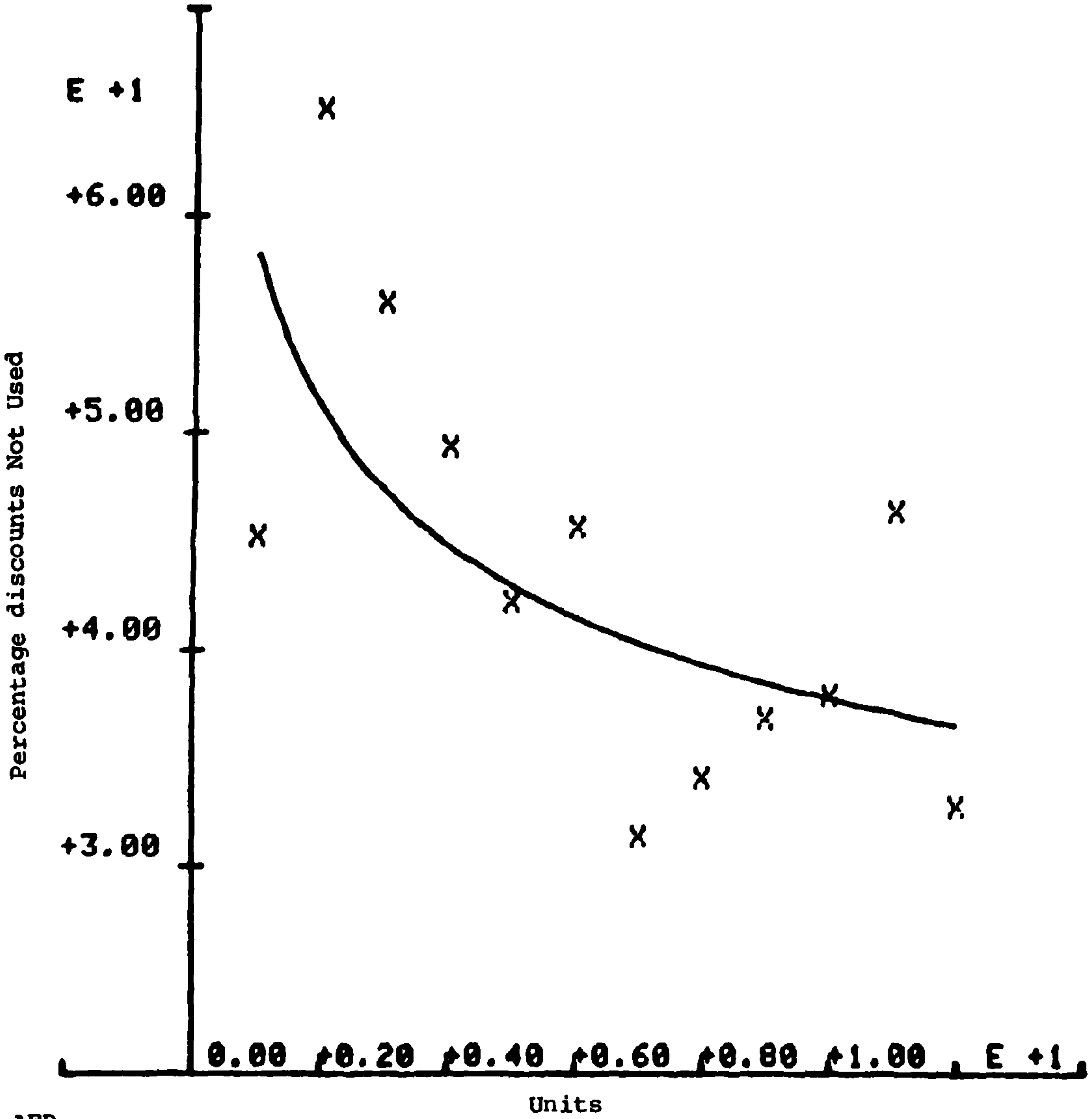
A =
58.1723960278

B =
-0.18926614662

R-SQUARE =
0.376978051745

RES ERROR
68.6262829482

MAX(ABS(RESIDUAL))
13.9797990548



BARKSDALE AFB

Y = A*X↑B

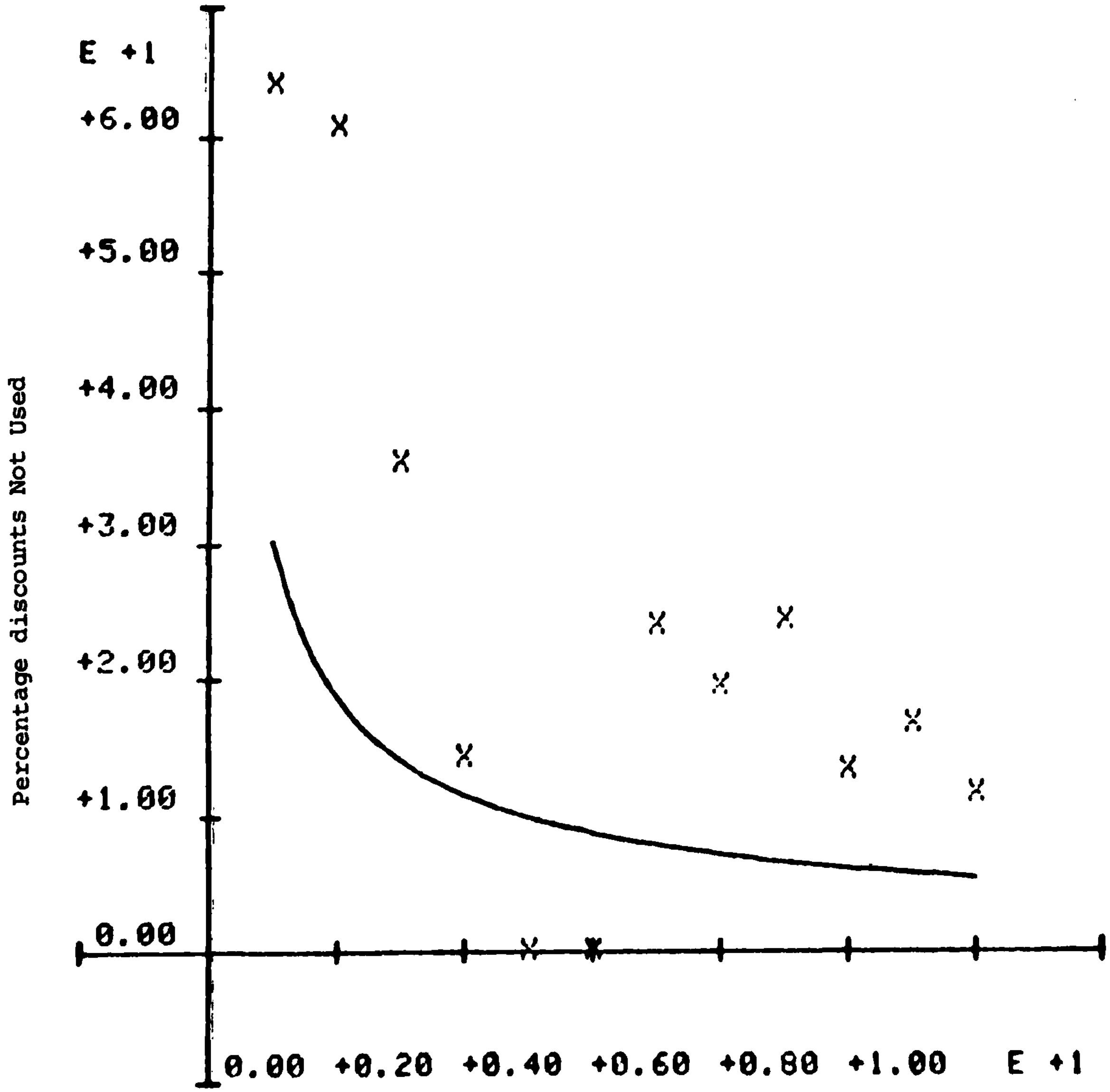
A =
30.1542154271

B =
-0.690792507477

R SQUARE =
0.0393576360397

RES ERROR
450.145163829

MAX(ABS(RESIDUAL))
42.1190581895



CHANUTE AFB

Y = A*X^B

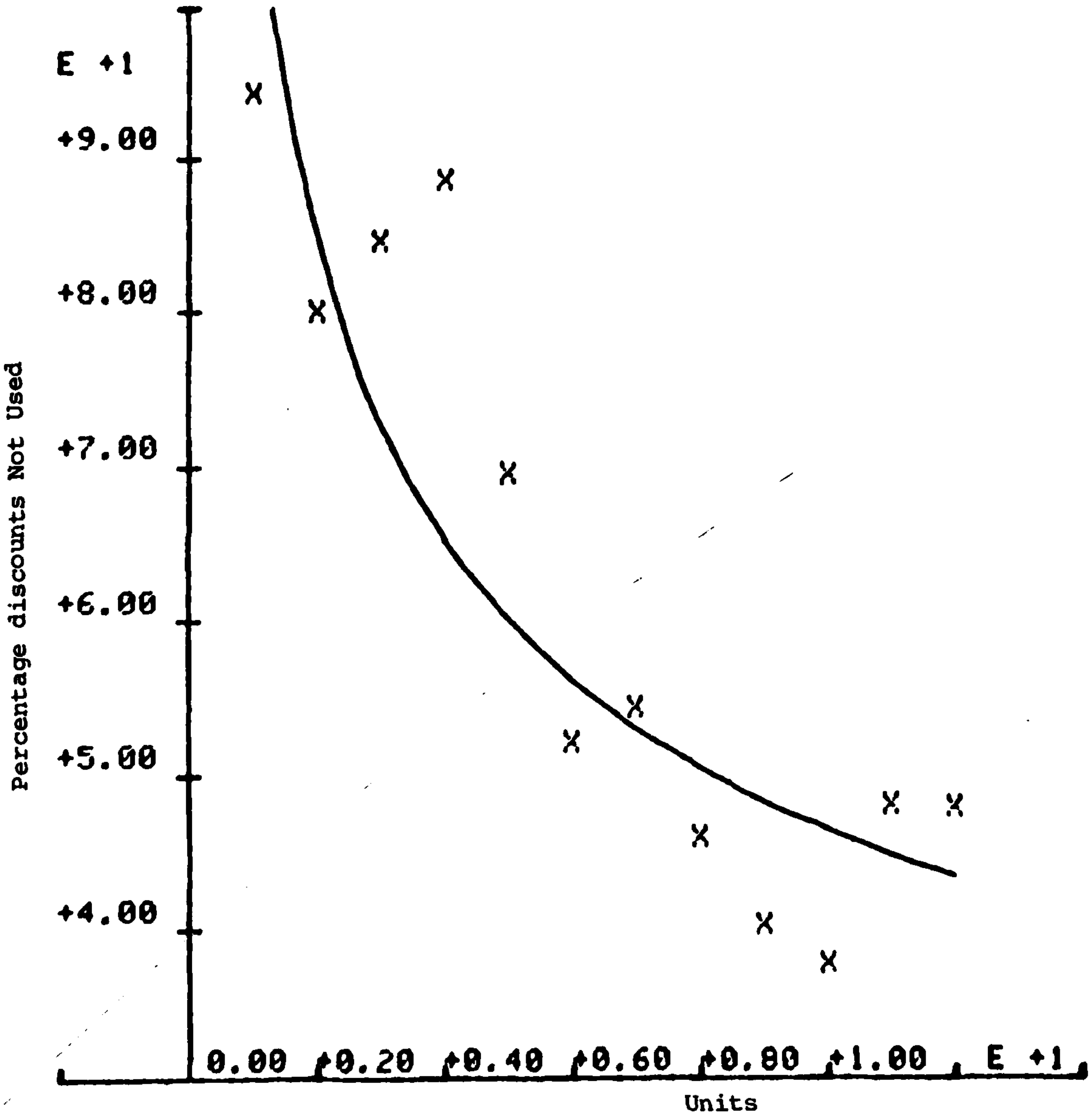
A =
110.1[illegible]269238

B =
-0.37[illegible]46741804

R-SQUARE =
0.725[illegible]1820699

RES ERROR
123.44789051

MAX(ABS(RESIDUAL))
22.991217565



CHARLESTON AFB

Y = AX^B

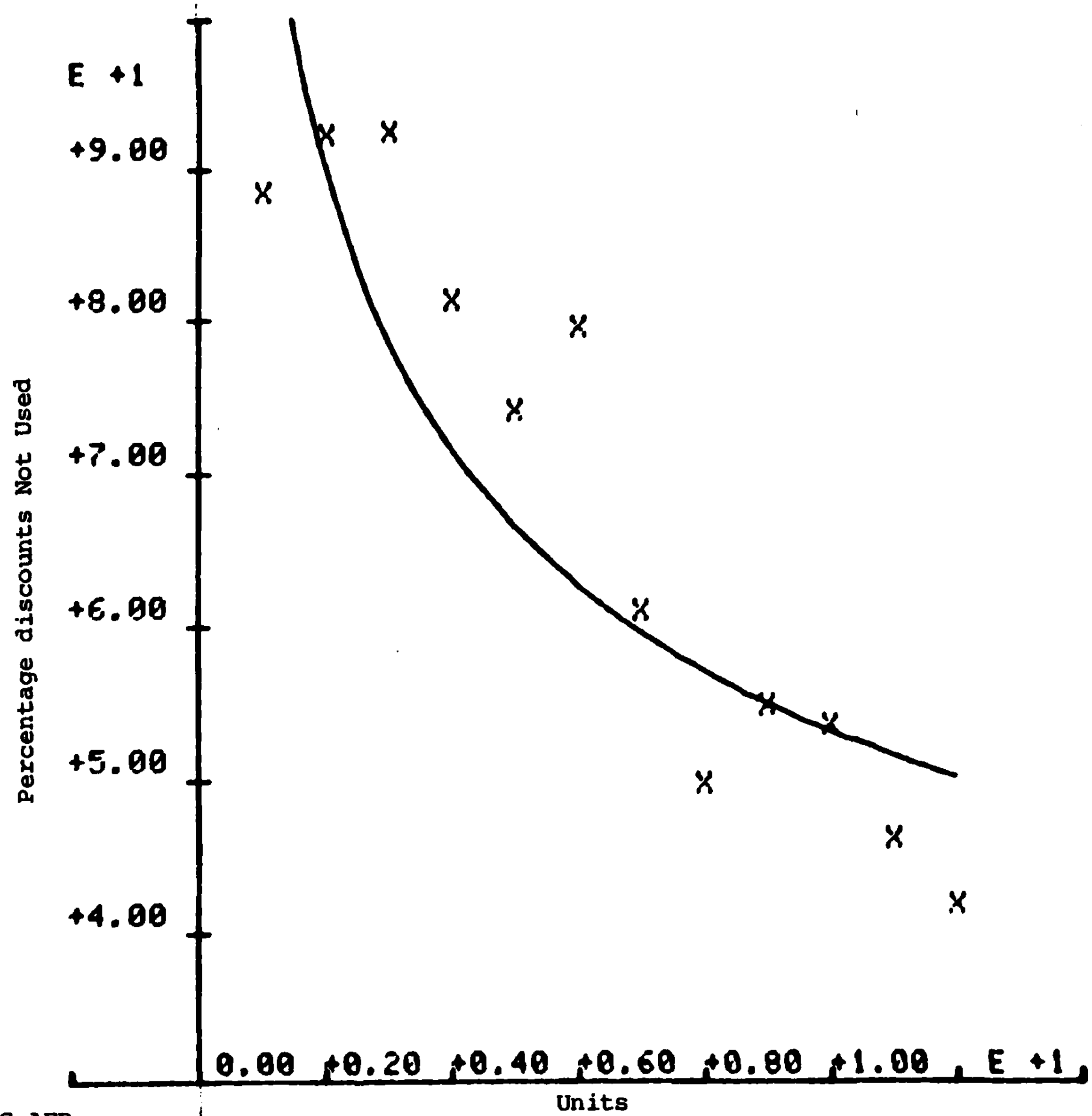
A =
112.641225983

B =
-0.327016309349

R-SQUARE =
0.648742510461

RES ERROR
135.865577353

MAX(ABS(RESIDUAL))
24.3412259825



GRIFFISS AFB

Y = A*X↑B

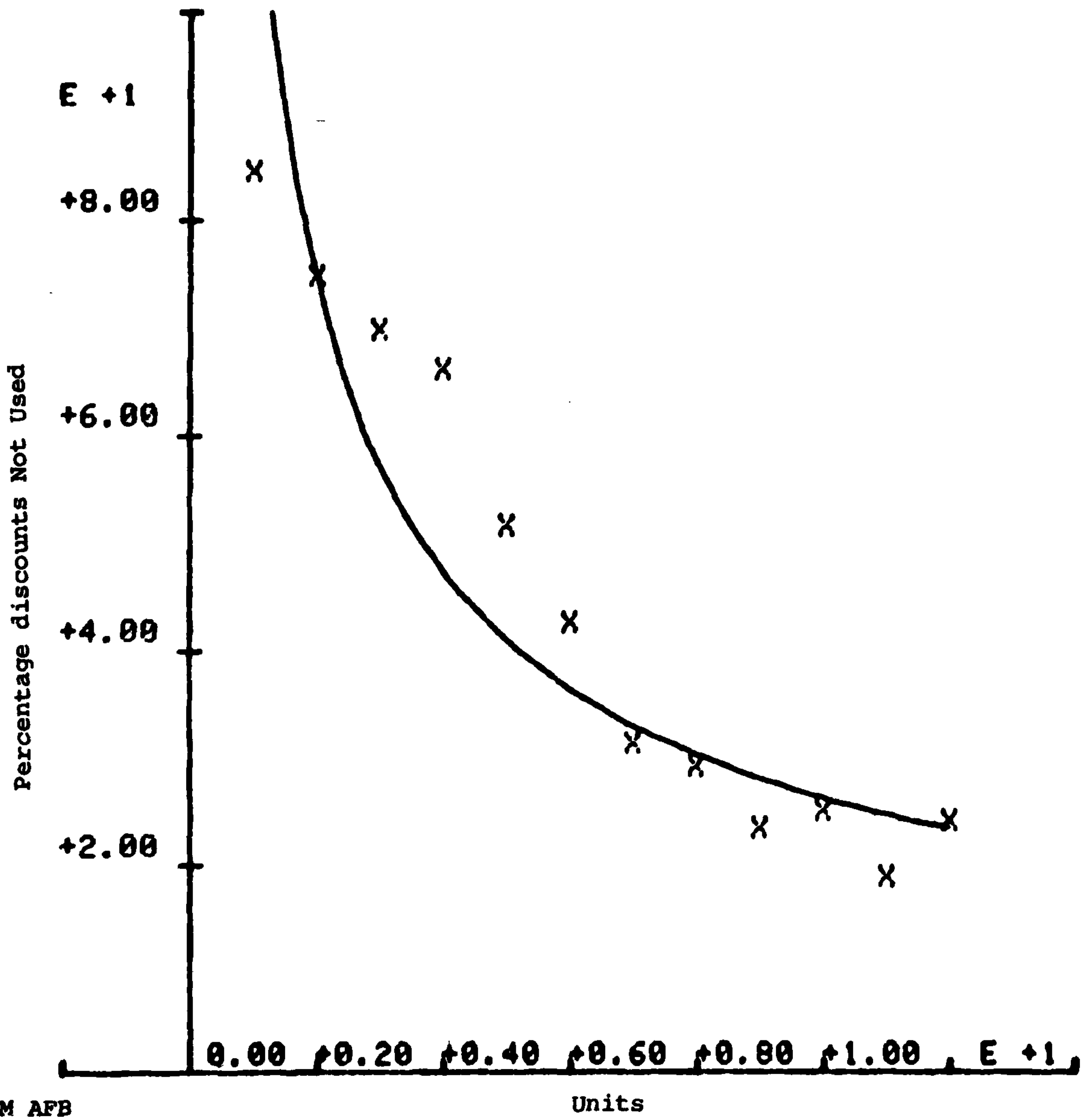
A =
116.995519097

B =
-0.651826401122

R-SQUARE =
0.706541320225

RES ERROR
176.054665758

MAX(ABS(RESIDUAL))
32.4955190972



HANSCOM AFB

Y = A*X↑B

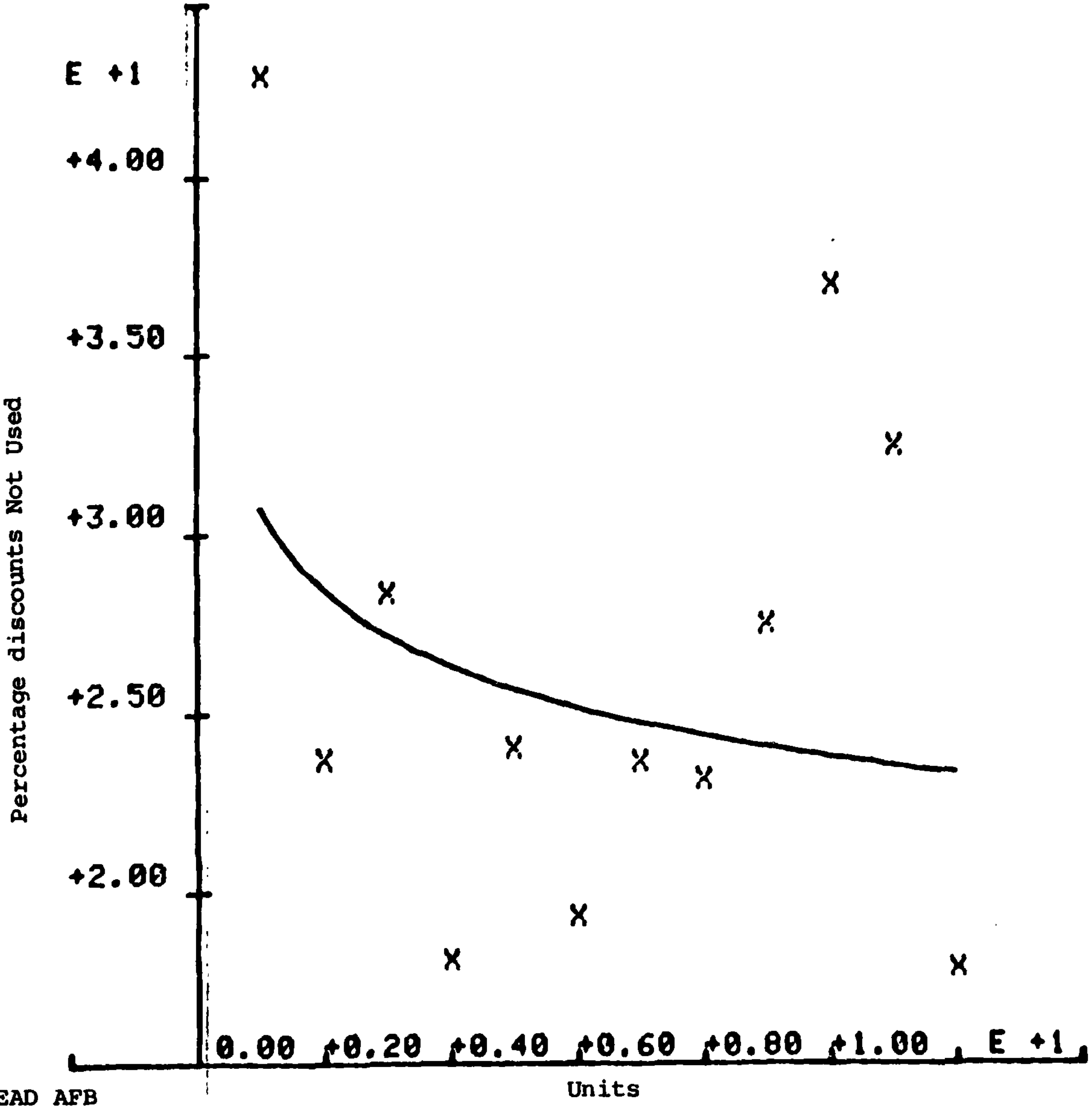
A =
30.7369677404

B =
-0.112274906132

R-SQUARE =
0.119285901501

RES ERROR
57.0933923279

MAX(ABS(RESIDUAL))
13.0652477803



HOMESTEAD AFB

Y = A*X↑B

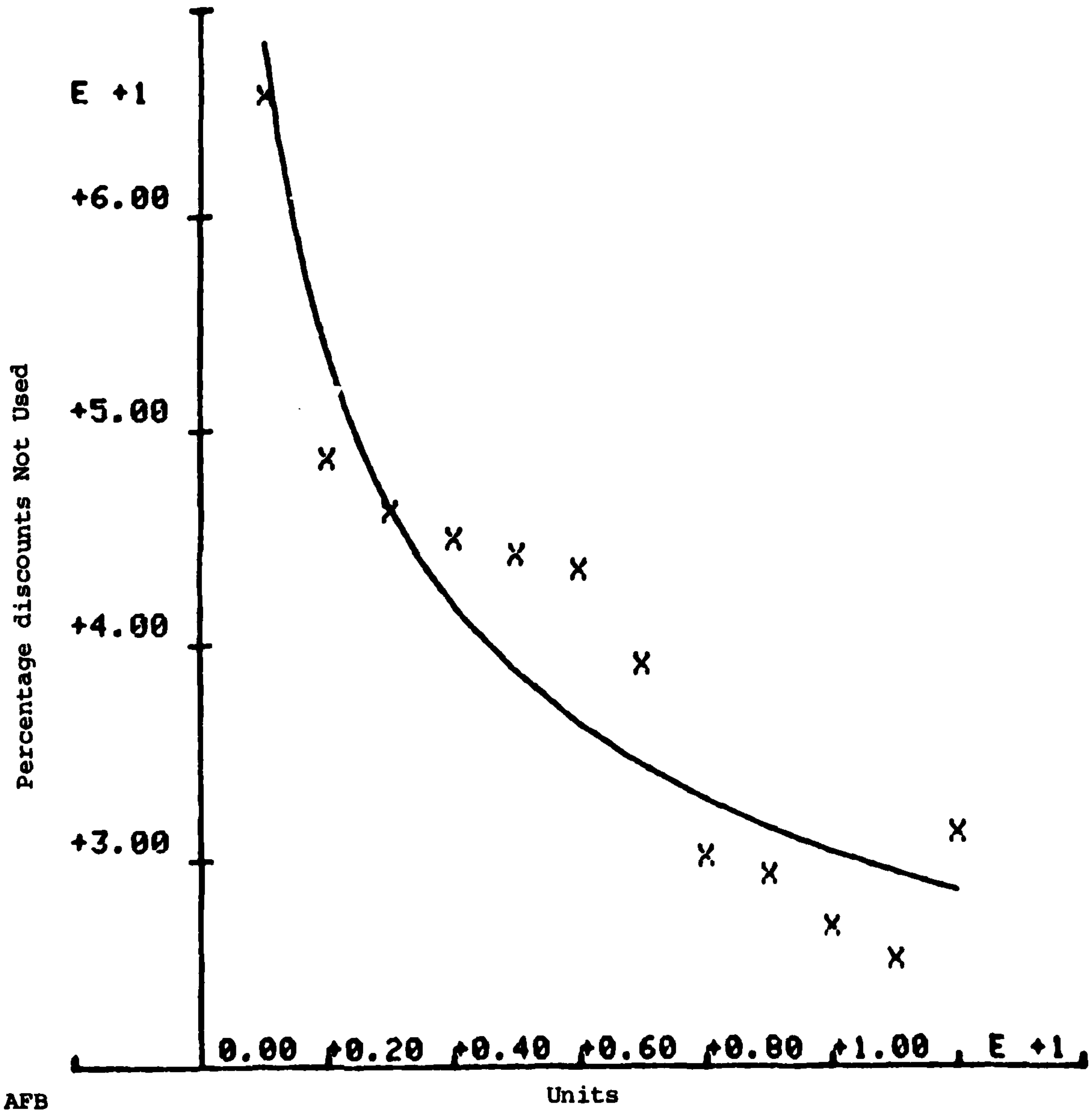
A =
68.3427145158

B =
-0.353124051233

R-SQUA[illegible] =
0.875[illegible]2309954

RES ER[illegible]R
18.82[illegible]835251

MAX(ABS(RESIDUAL))
6.99985978136



KEESLER AFB

Y = A* ↑B

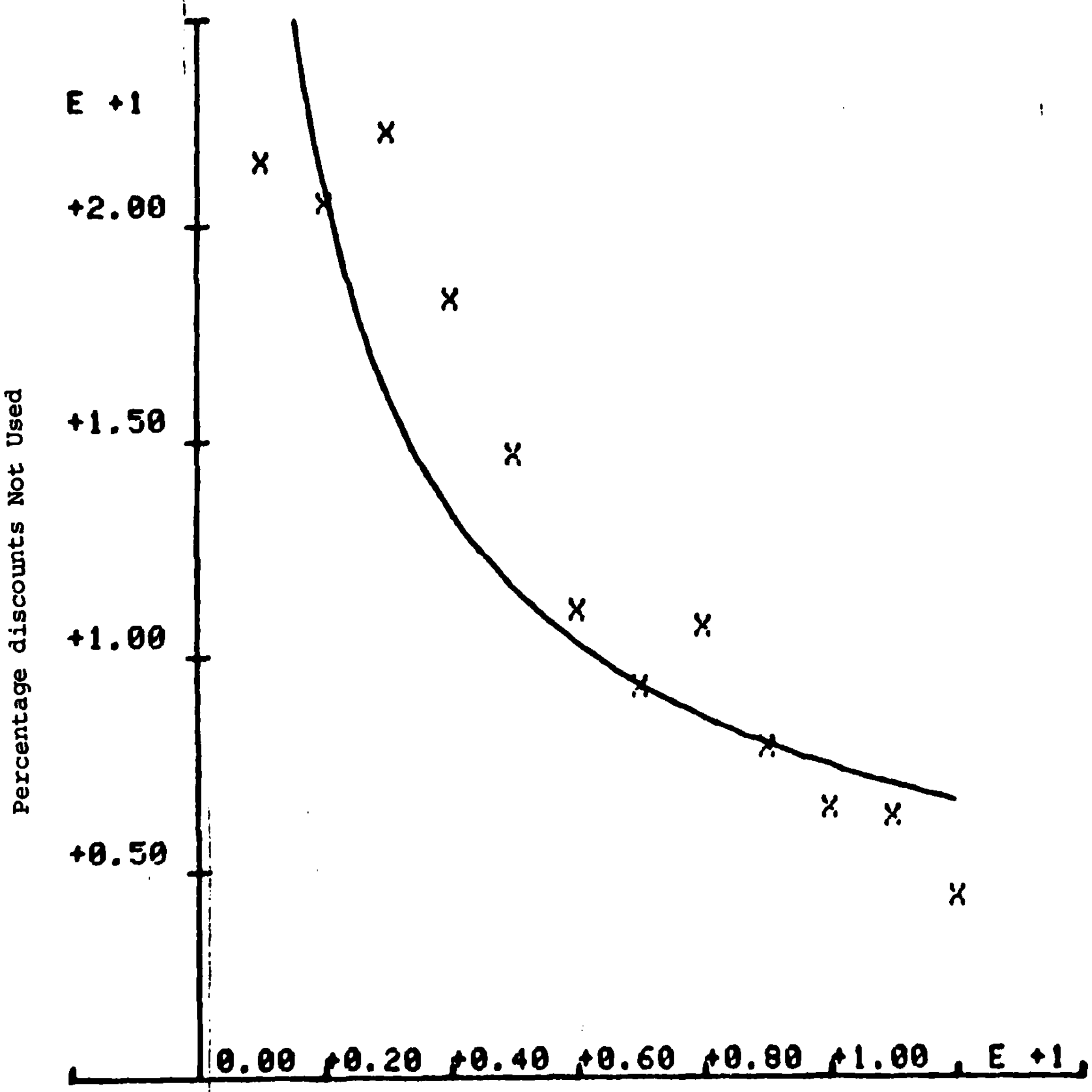
A =
32.70 4958764

B =
-0.645884554215

R-SQUARE =
0.547844232064

RES ERROR
20.7290435014

MAX(ABS(RESIDUAL))
11.2094958764



KIRTLAND AFB

Y = A*X↑B

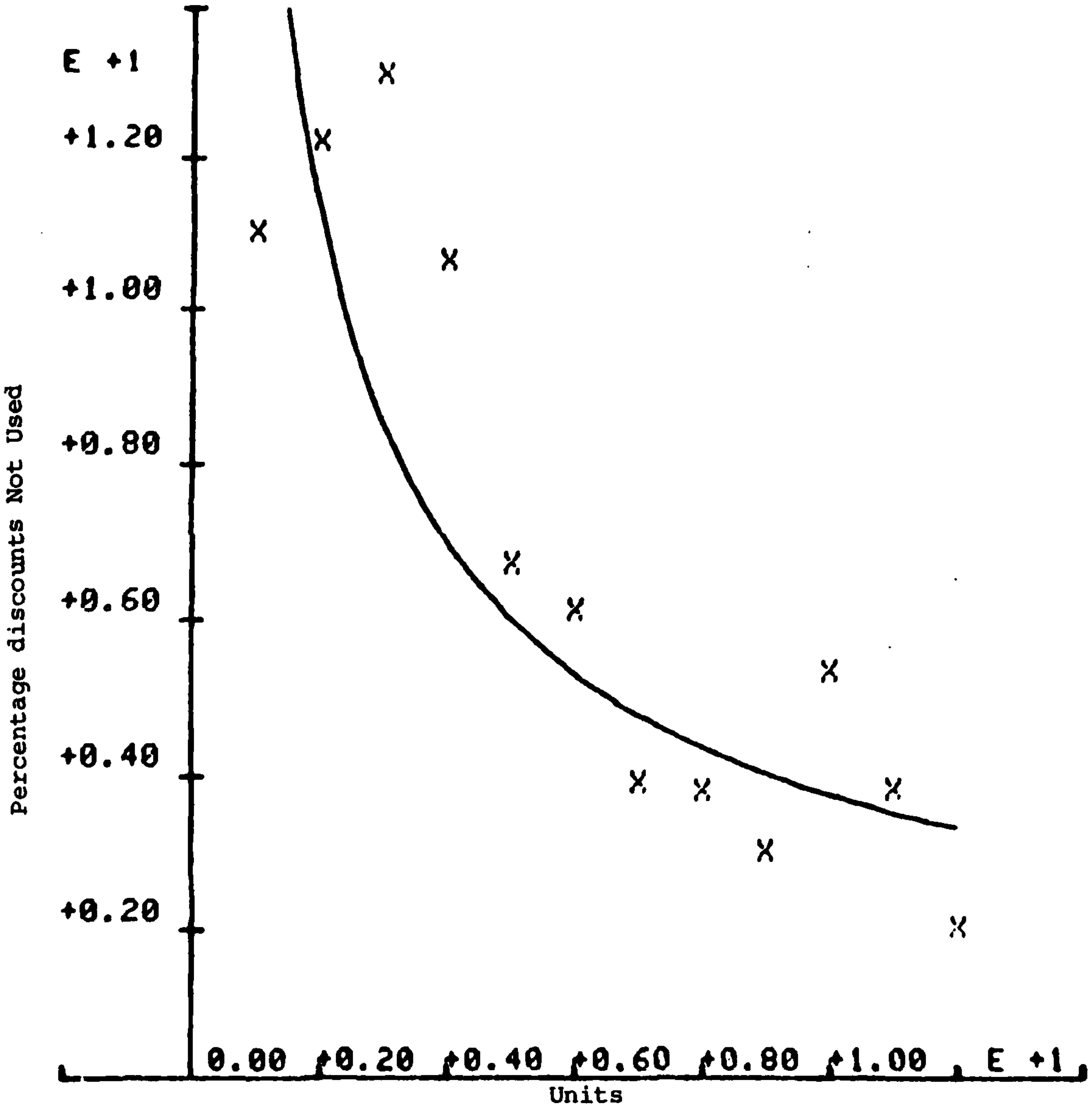
A =
18.0258973426

B =
-0.683840905143

R-SQUARE =
0.451259210563

RES ERROR
9.1952036802

MAX(ABS(RESIDUAL))
7.02589734256



LACKLAND AFB

AD-A122 865 ANALYSIS OF DOD TRAVEL MANAGEMENT: AN APPLICATION OF LEARNING CURVE THEORY(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. 3/3

UNCLASSIFIED S S ANDERSON ET AL. SEP 82 AFIT-LSSR-72-82 F/G 12/1 NL

END

FILMED

DTIC

1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Y = A*X↑B

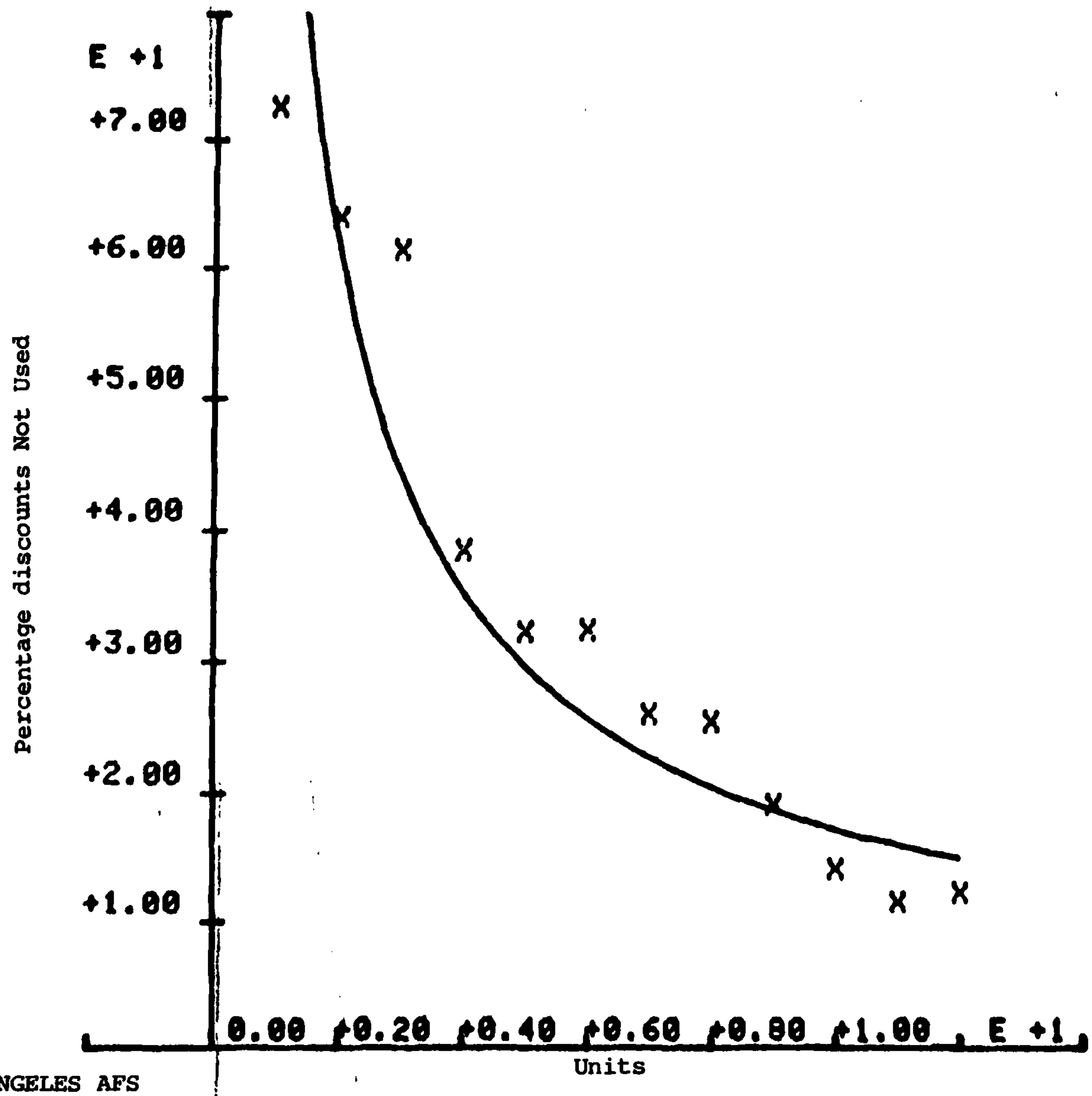
A =
105.813703842

B =
-0.792871696522

R-SQUARE =
0.6876834221

RES ERROR
153.159086826

MAX(ABS(RESIDUAL))
33.3137038416



LOS ANGELES AFS

Y = A*X↑B

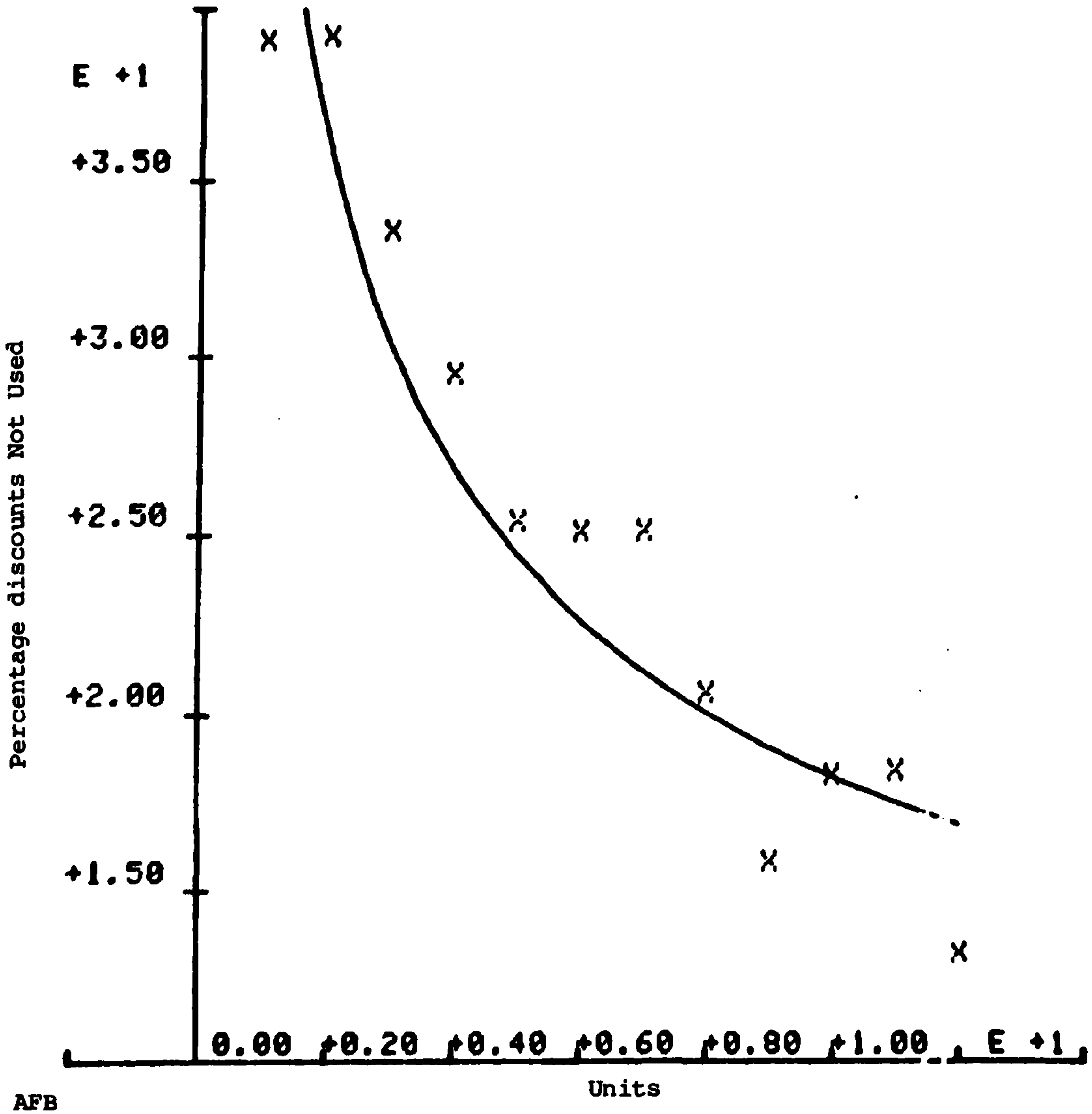
A =
48.4083502017

B =
-0.425467886174

R-SQUARE =
0.804598171687

RES ERROR
16.0959650715

MAX(ABS(RESIDUAL))
9.40835020171



LOWRY AFB

Y = A*X↑B

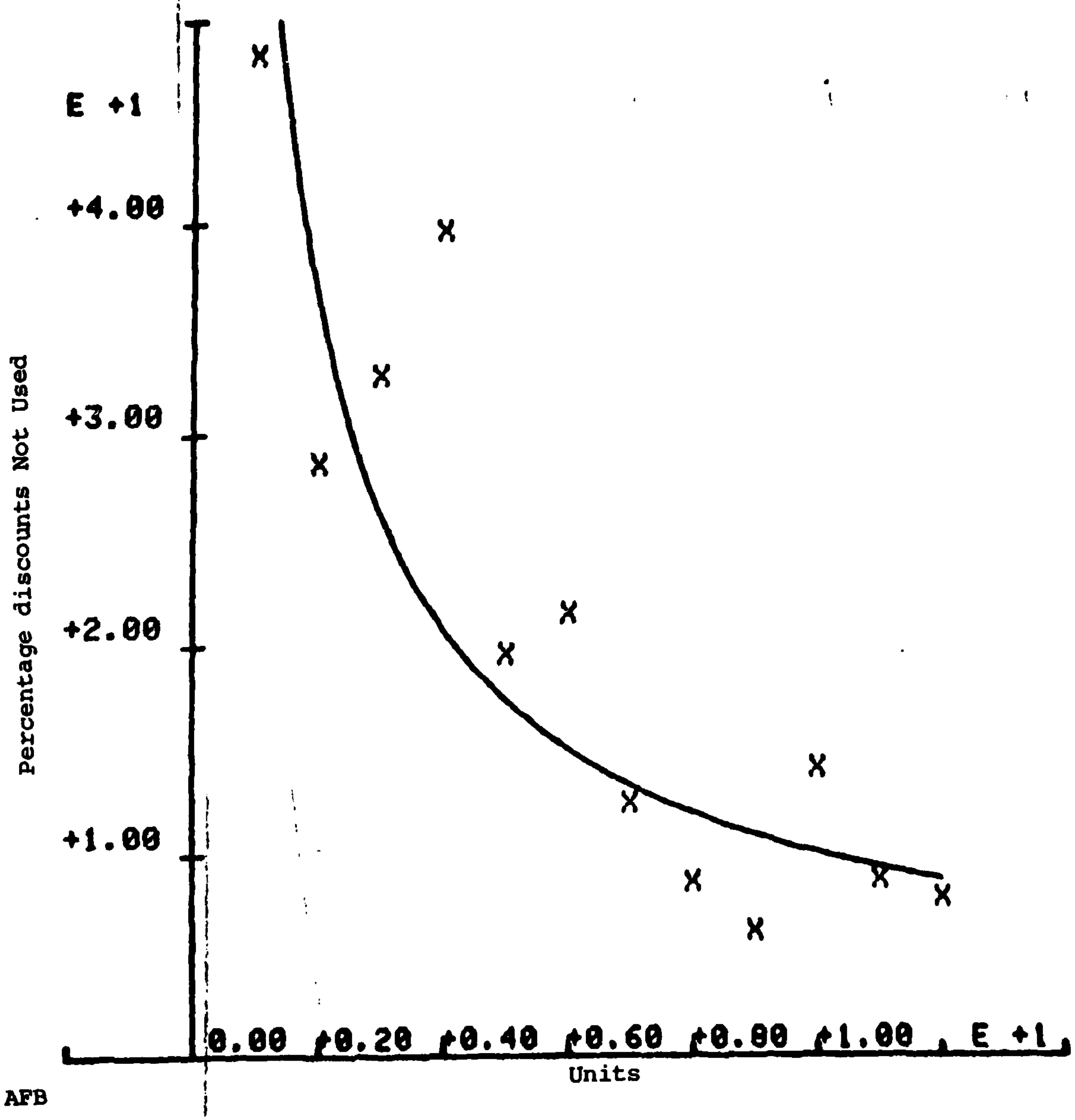
A =
62.7834791049

B =
-0.79815722445

R-SQUARE =
0.636952429537

RES ERROR
76.6502335519

MAX(ABS(RESIDUAL))
18.8361995456



Y = A*X↑B

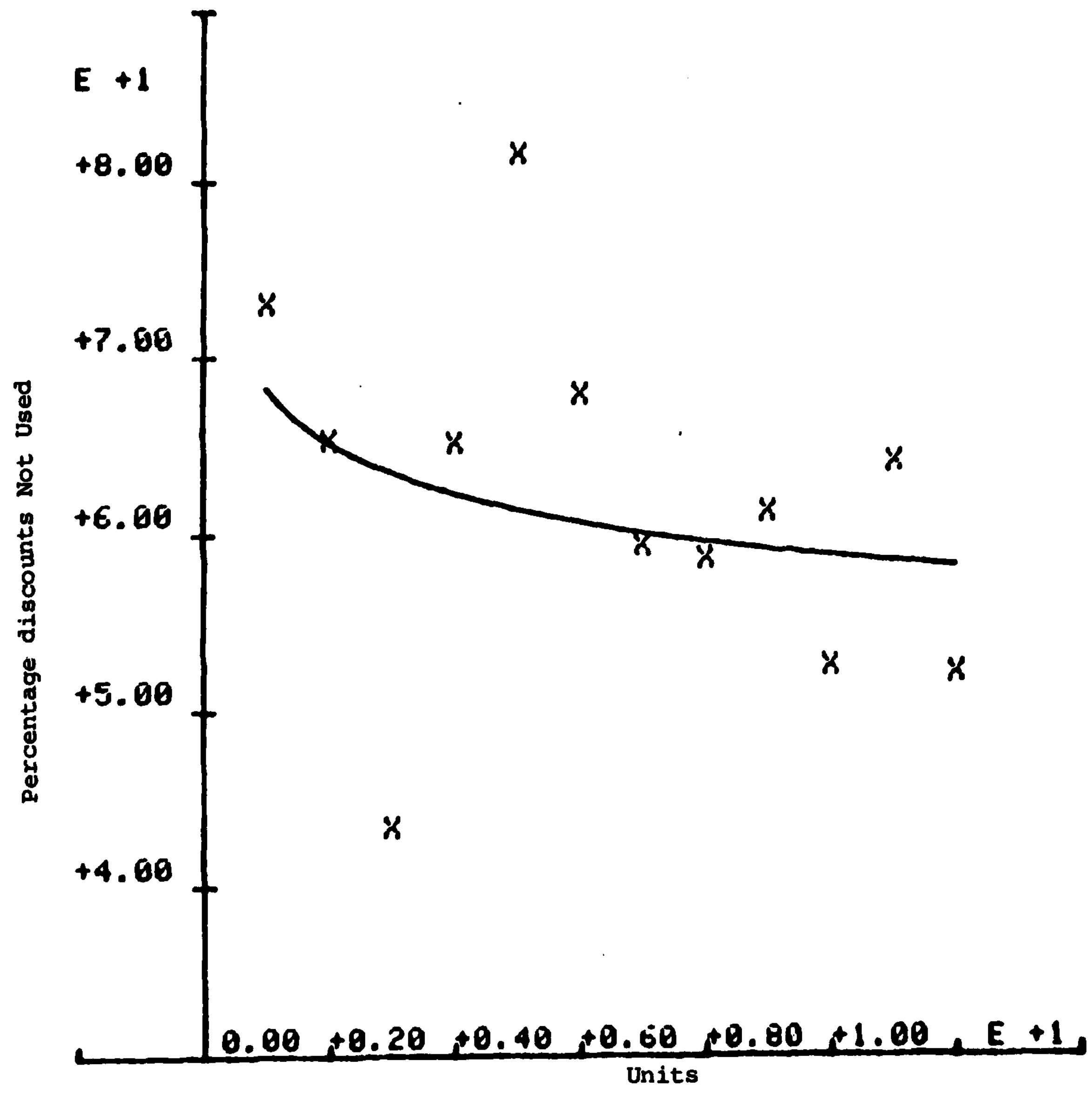
A =
68.1588004424

B =
-0.0662651640648

R-SQUARE =
0.105579459257

RES ERROR
100.308294689

MAX(ABS RESIDUAL))
20.1361089782



MAXWELL AFB

Y = A*X↑B

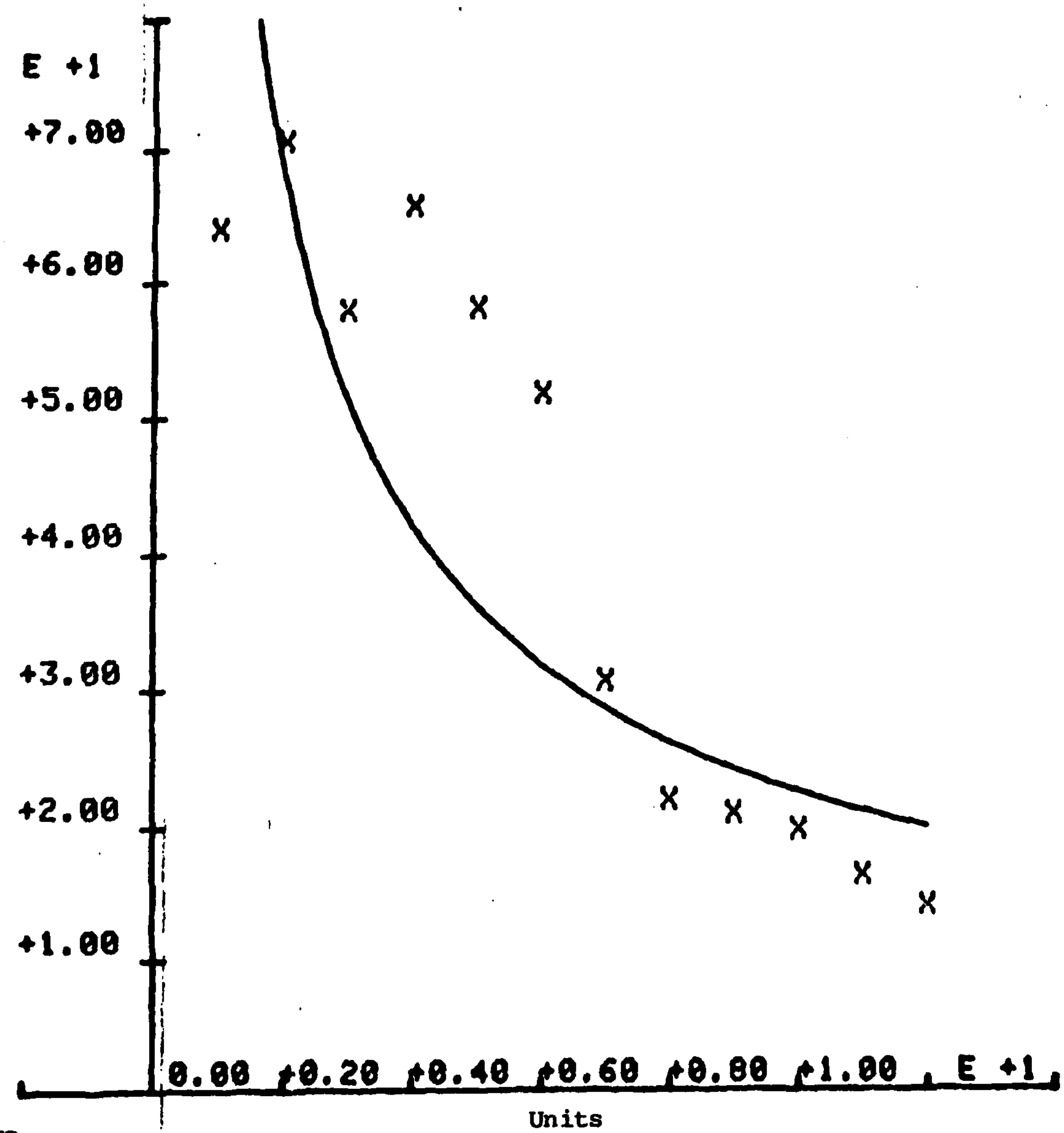
A =
109.65974286

B =
-0.690926794772

R-SQUARE =
0.321777855168

RES ERROR
366.000489274

MAX(ABS(RESIDUAL))
45.75974286



McGUIRE AFB

Y = A*X↑B

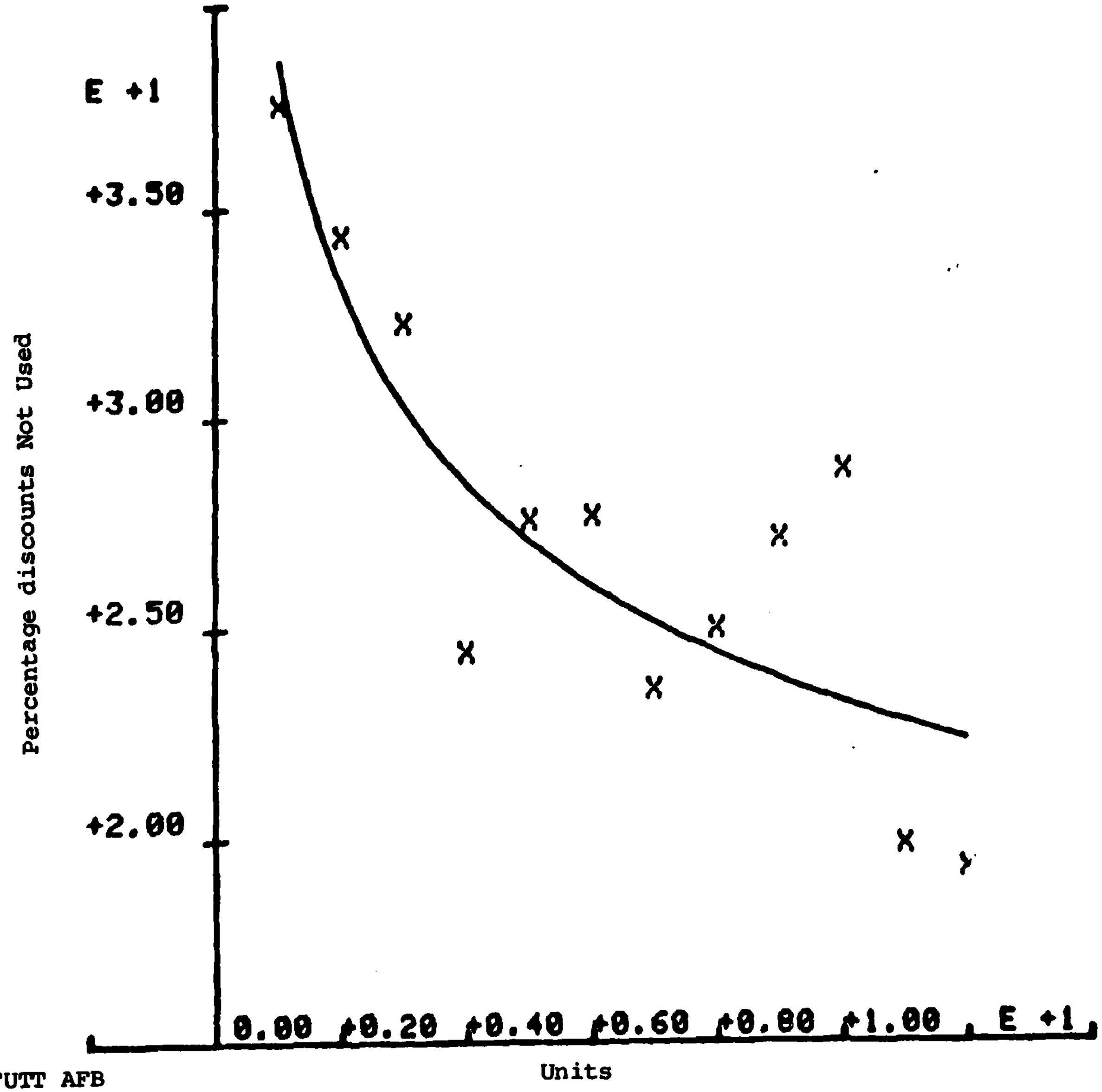
A =
38.6250577089

B =
-0.221495250274

R-SQUARE =
0.73919115322

RES ERROR
8.58919601694

MAX(ABS(RESIDUAL))
5.40609409059



OFFUTT AFB

Y = A*X↑B

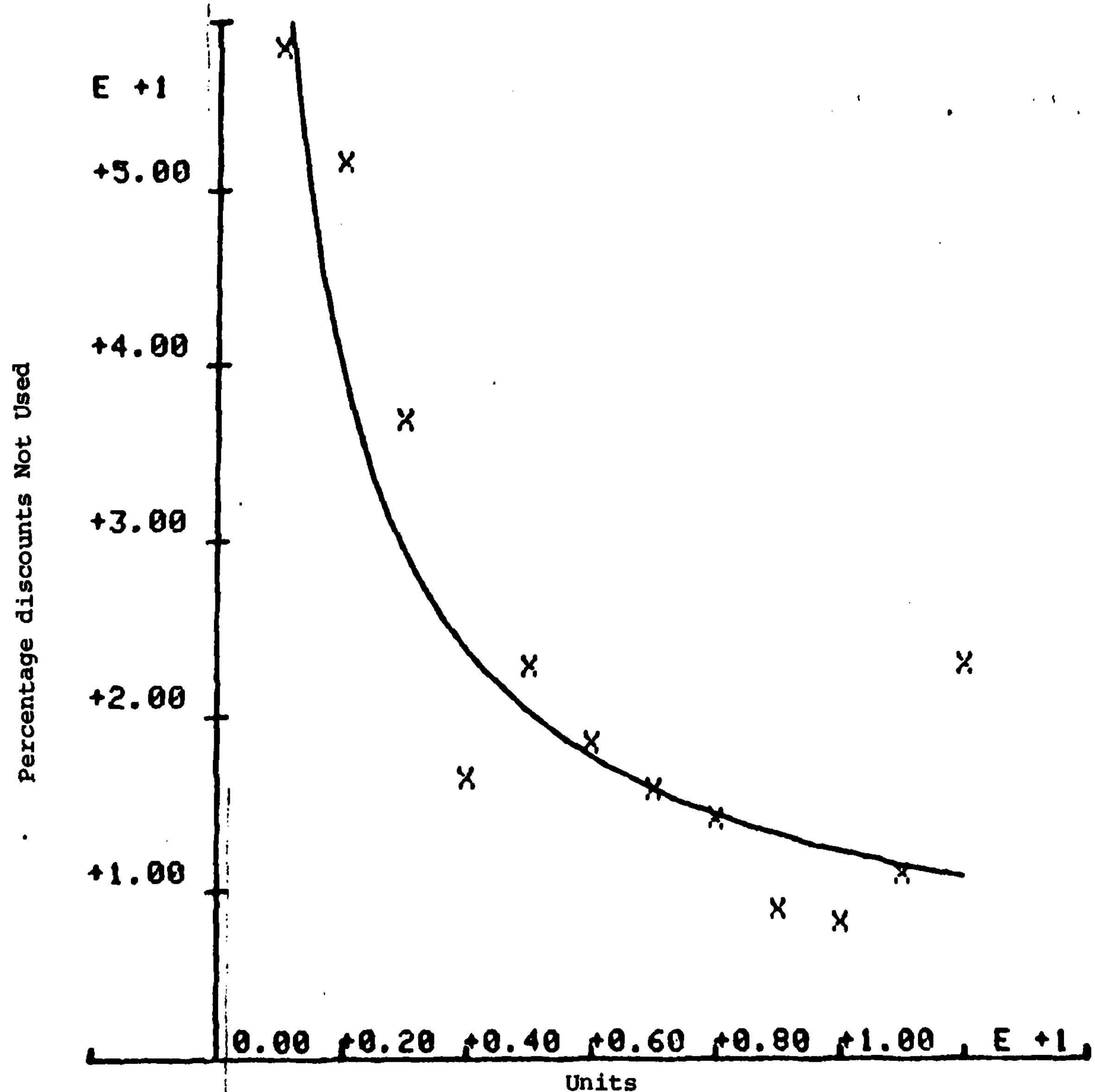
A =
65.6122517817

B =
-0.732251244911

R-SQUARE =
0.836705224602

RES ERROR
49.308640066

MAX(ABS(RESIDUAL))
12.0037963325



PATRICK AFB

Y = A*X↑B

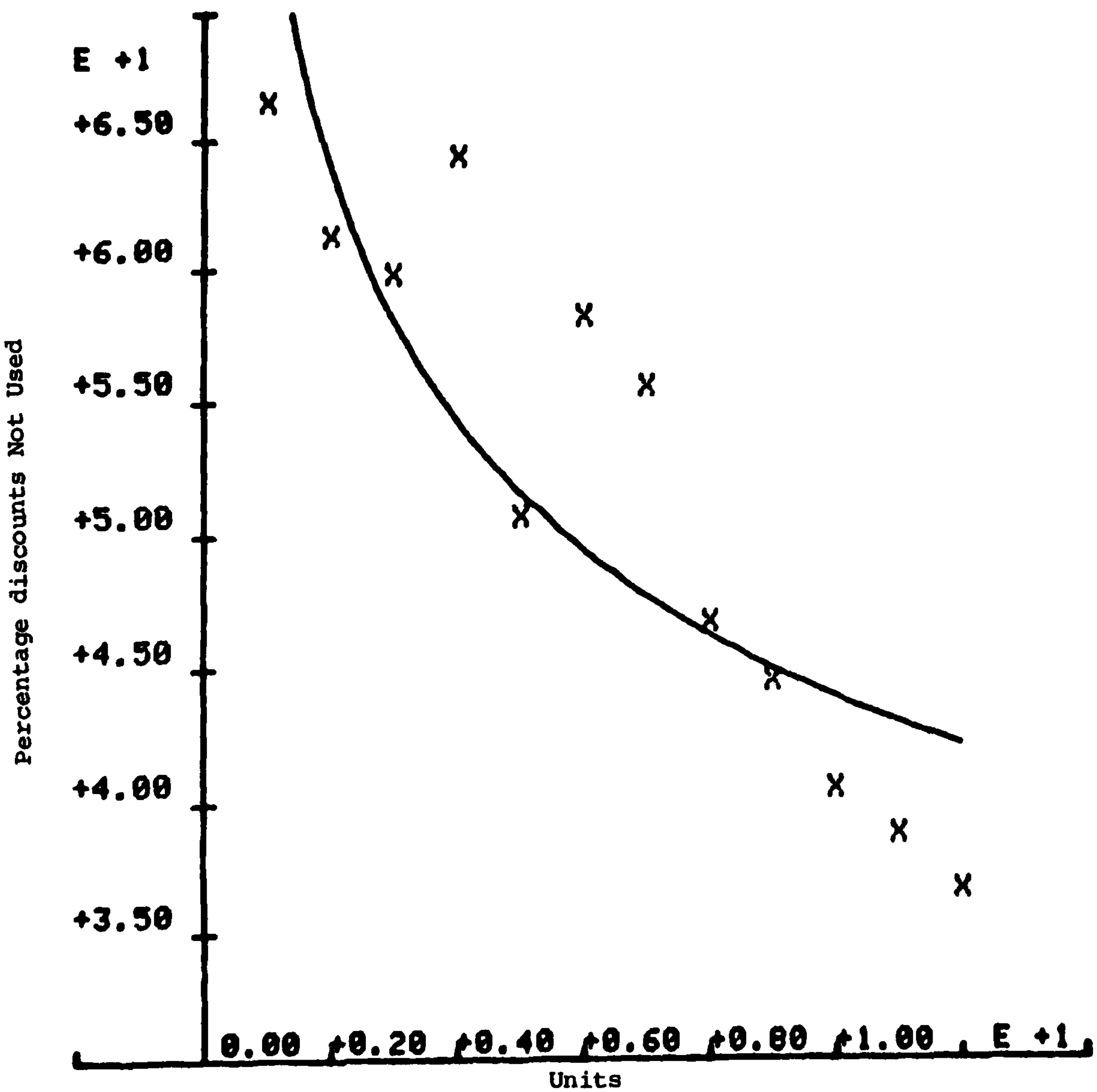
A =
75.0263653259

B =
-0.233340202888

R-SQUARE =
0.680142261477

RES ERROR
38.1171001873

MAX(ABS(RESIDUAL))
10.0088417628



SCOTT AFB

Y = A*X^B

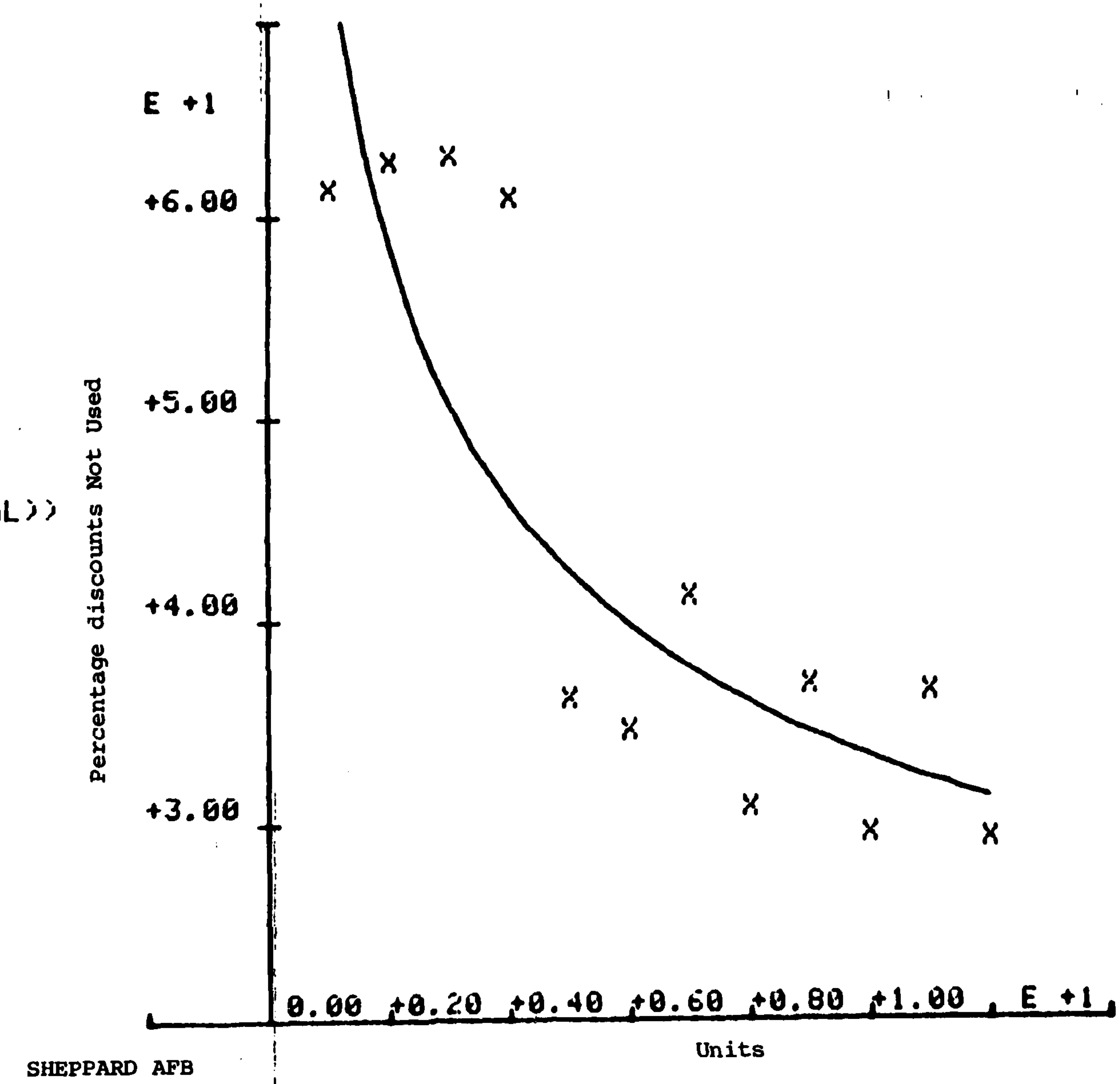
A =
74.6450478154

B =
-0.35179087732

R-SQUARE =
0.670106985481

RES ERROR
71.6803638025

MAX(ABS(RESIDUAL))
14.9645195486



Y = A*X↑B

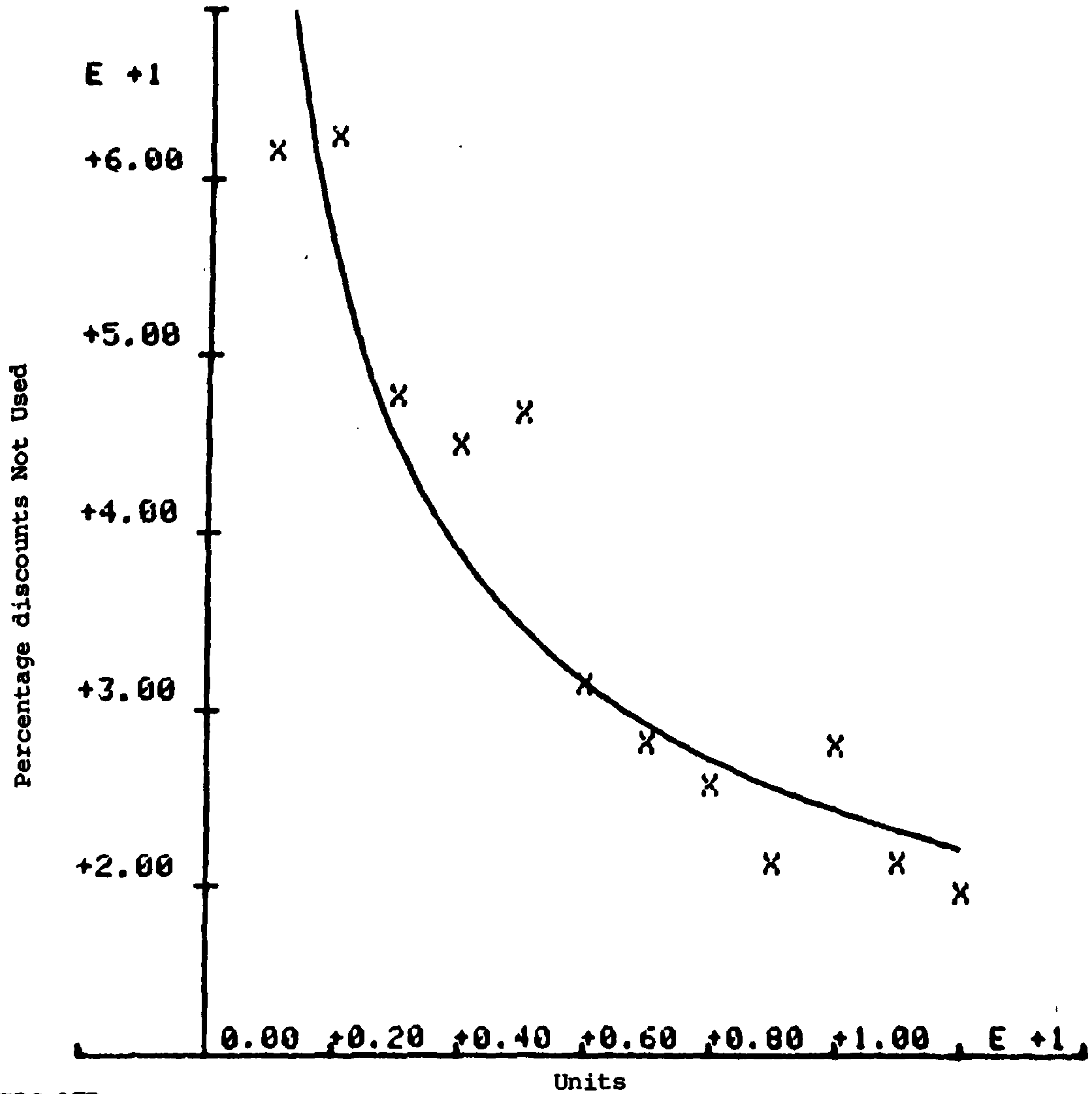
A =
79.1111864007

B =
-0.514229954748

R-SQUARE =
0.778442830813

RES ERROR
58.5844928594

MAX(ABS(RESIDUAL))
17.5111864007



VANDENBERG AFB

Y = A*X↑B

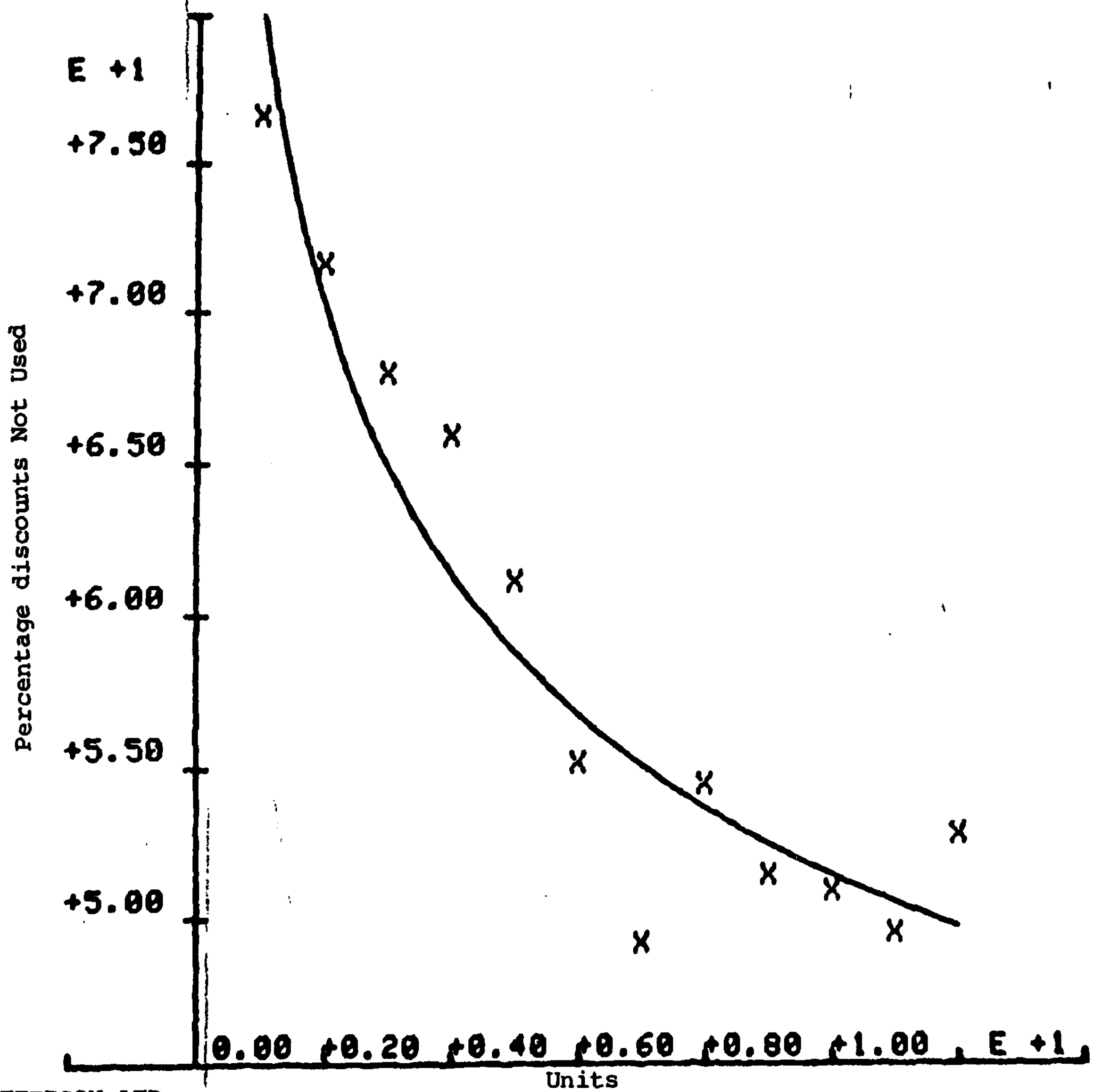
A =
80.2574034337

B =
-0.19356758843

R-SQUARE =
0.897725874052

RES ERROR
10.0504783569

MAX(ABS(RESIDUAL))
5.9682804249



WRIGHT-PATTERSON AFB

APPENDIX F

LEARNING CURVE SLOPES PLOTTED BY MONTH PERFORMED BY THE PLOT 50 SIMPLE LINEAR REGRESSION PACKAGE

Base	Plot 50
Barksdale	87.70
Chanute	61.95
Charleston	77.08
Griffiss	79.72
Hanscom	63.65
Homestead	92.51
Keesler	78.29
Kirtland	63.91
Lackland	62.25
Los Angeles	57.72
Lowry	74.46
March	57.51
Maxwell	95.51
McGuire	61.95
Offutt	85.77
Patrick	60.19
Scott	85.07
Sheppard	78.36
Vandenberg	70.02
Wright-Patterson	87.44
Aggregate	78.65

APPENDIX G

SELECTING THE BEST FIT EQUATION FOR EACH SAMPLE BASE AND THE AGGREGATE

SELECT BEST FIT

AGGREGATE

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	3.95308		861.33088	-5.83672	54.34692
Y = A + B*X	56.84091	-2.86783	8.37620	0.93351	4.56608
Y = A*EXP(B*X)	59.75482	-0.07418	4.02458	0.96806	3.35241
Y = 1/(A + B*X)	0.01506	0.00199	2.76911	0.97802	2.78531
Y = A + B/X	29.08695	35.23984	31.29724	0.75158	8.30309
Y = A + B*LOG(X)	61.27024	-13.85100	5.42397	0.95695	4.13132
Y = A*X↑B	65.70453	-0.34646	13.12890	0.89579	7.40453
Y = X/(A + B*X)	-0.02131	0.03353	97.17798	0.22866	23.52970

EQU ION Y = 1/(A + B*X) HAS MAXIMUM R-SQUARE

EQU ION Y = 1/(A + B*X) HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

BARKSDALE AFB

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	4.79969		876.48799	-6.95717	55.40062
Y = A + B*X	55.61515	-1.87413	59.92409	0.45598	13.13310
Y = A*EXP(B*X)	55.62513	-0.04161	58.75990	0.46655	13.81662
Y = 1/(A + B*X)	0.01789	0.00095	59.49654	0.45986	14.49283
Y = A + B/X	38.94607	17.35207	87.19273	0.20842	17.37789
Y = A + B*LOG(X)	57.62705	-8.52168	64.51558	0.41430	13.27972
Y = A*X↑B	58.17240	-0.18927	68.62628	0.37698	13.97980
Y = X/(A + B*X)	-0.00913	0.02645	99.94426	0.09266	19.29345

EQUATION Y = A*EXP(B*X) HAS MAXIMUM R-SQUARE

EQUATION Y = A + B*X HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

CHANUTE AFB

SELECT BEST FIT

EQUATION / A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X 2.07015		793.94912	-0.69434	62.02985
Y = A + B*X 46.48788	-3.50839	90.10022	0.80772	21.32890
Y = A*EXP(B*X) 13.00527	-0.04763	507.15553	-0.08231	51.69968
Y = 1/(A + B*X) 2.58079	-0.13439	770.08057	-0.64341	63.69124
Y = A + B/X 7.09536	64.14506	51.89337	0.88926	21.63211
Y = A + B*LOG(X) 58.82564	-21.09887	30.33450	0.93526	16.59898
Y = A*X↑B 30.15422	-0.69079	292.63314	0.37550	42.11906
Y = X/(A + B*X) -2.02421	2.23071	710.89580	-0.51710	59.97939

EQUATION Y = A + B*LOG(X) HAS MAXIMUM R-SQUARE

EQUATION Y = A + B*LOG(X) HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

CHARLESTON AFB

EQUATION / A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X				
6.31308		2445.41688	-4.42910	87.88692
Y = A + B*X				
94.46212	-5.02238	89.72051	0.80081	14.02739
Y = A*EXP(B*X)				
99.08153	-0.08003	73.59637	0.83661	16.46122
Y = 1/(A + B*X)				
0.00912	0.00133	75.80118	0.83171	19.22183
Y = A + B/X				
46.50838	59.19659	183.23540	0.59320	27.09248
Y = A + B*LOG(X)				
101.78922	-23.99887	88.49306	0.80354	19.88028
Y = A*X↑B				
110.10269	-0.37565	123.44789	0.72593	22.99122
Y = X/(A + B*X)				
-0.01448	0.02153	455.62092	-0.01153	47.[illegible]338

EQUATION Y = A*EXP(B*X) HAS MAXIMUM R-SQUARE

EQUATION Y = A + B*X HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

GRIFFISS AFB

EQUATION / A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X				
7.03954		2679.21239	-5.92665	81.26046
Y = A + B*X				
100.11970	-4.97483	32.88860	0.91497	10.62110
Y = A*EXP(B*X)				
107.12019	-0.07606	39.66279	0.89746	11.43221
Y = 1/(A + B*X)				
0.00804	0.00121	73.34281	0.81038	19.83132
Y = A + B/X				
55.22457	48.56428	206.96674	0.46492	20.88734
Y = A + B*LOG(X)				
104.14314	-21.82984	87.33024	0.77422	15.84314
Y = A*X↑B				
112.64123	-0.32702	135.86558	0.64874	24.34123
Y = X/(A + B*X)				
-0.01093	0.01872	388.94266	-0.00555	40.03418

EQUATION Y = A + B*X HAS MAXIMUM R-SQUARE

EQUATION Y = A + B*X HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

HANSCOM AFB

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	4.02092		1968.23354	-2.28077	80.47908
Y = A + B*X	85.29091	-6.21399	47.75520	0.92040	12.97692
Y = A*EXP(B*X)	100.14830	-0.14311	21.62361	0.96396	9.4[illegible]107
Y = 1/(A + B*X)	0.00429	0.00375	204.74142	0.65872	39.[illegible]281
Y = A + B/X	25.82521	73.76152	185.08085	0.69150	21.63441
Y = A + B*LOG(X)	94.37621	-29.70471	45.43301	0.92427	12.70327
Y = A*X↑B	116.99552	-0.65183	176.05467	0.70654	32.49552
Y = X/(A + B*X)	-0.03649	0.03808	29935.94302	-48.89906	544.21404

EQUATION Y = A*EXP(B*X) HAS MAXIMUM R-SQUARE

EQUATION Y = A*EXP(B*X) HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT HOMESTEAD AFB

EQUATION A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X 3.10046		277.92699	-3.28726	39.79954
Y = A + B*X 28.50909	-0.32063	63.35616	0.02268	14.71154
Y = A*EXP(B*X) 27.24755	-0.01023	64.30653	0.00802	15.92982
Y = 1/(A + B*X) 0.03812	0.00037	66.95334	-0.03281	16.92511
Y = A + B/X 22.32379	15.85922	45.64866	0.29583	12.89029
Y = A + B*LOG(X) 32.29593	-3.52481	57.01861	0.12044	12.62025
Y = A*X↑B 30.73687	-0.11227	57.09339	0.11929	13.06525
Y = X/(A + B*X) -0.01711	0.04498	45.28320	0.30147	13.68916

EQUATION Y = X/(A + B*X) HAS MAXIMUM R-SQUARE

EQUATION Y = A + B*LOG(X) HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

KEESLER AFB

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	4.08031		937.20579	-5.20531	61.61969
Y = A + B*X	58.80152	-2.97587	24.39459	0.83848	9.87436
Y = A*EXP(B*X)	61.67798	-0.07470	19.26620	0.87244	8.46154
Y = 1/(A + B*X)	0.01456	0.00197	16.50023	0.89075	5.56926
Y = A + B/X	29.21807	39.59873	31.47094	0.79163	7.71795
Y = A + B*LOG(X)	63.97549	-14.71970	14.87388	0.90152	5.69868
Y = A*X↑B	68.34271	-0.35312	18.82288	0.87537	6.99986
Y = X/(A + B*X)	-0.02162	0.03295	94.91613	0.37155	22.57349

EQUATION Y = A + B*LOG(X) HAS MAXIMUM R-SQUARE

EQUATION Y = 1/(A + B*X) HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

KIRTLAND AFB

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	1.14477		154.46472	-2.36929	20.35523
Y = A + B*X	23.94242	-1.72832	3.12945	0.93174	3.44254
Y = A*EXP(B*X)	29.33850	-0.14877	3.80673	0.91697	3.78290
Y = 1/(A + B*X)	0.00529	0.01503	85.55403	-0.86616	27.69863
Y = A + B/X	7.93145	18.47203	19.82777	0.56750	8.11121
Y = A + B*LOG(X)	25.85369	-7.89226	6.70217	0.85381	5.01684
Y = A*X↑B	32.70950	-0.64588	20.72904	0.54784	11.20950
Y = X/(A + B*X)	-0.13102	0.13688	2251.96451	-48.12136	149.03173

EQUATION Y = A + B*X HAS MAXIMUM R-SQUARE

EQUATION Y = A + B*X HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

LACKLAND AFB

EQUATION / A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X				
0.60108		48.62492	-1.90178	11.29677
Y = A + B*X				
13.11212	-0.97238	3.23601	0.80689	2.90501
Y = A*EXP(B*X)				
15.70235	-0.15400	2.99633	0.82119	3.20720
Y = 1/(A + B*X)				
0.01089	0.02988	21.25590	-0.26849	13.52679
Y = A + B/X				
4.14457	10.23623	8.76758	0.47678	5.54335
Y = A + B*LOG(X)				
14.24544	-4.47512	4.17176	0.75104	3.77099
Y = A*X↑B				
18.02590	-0.68384	9.19520	0.45126	7.02590
Y = X/(A + B*X)				
-0.27204	0.27547	7863.14559	-468.24776	280.17667

EQUATION Y = A*EXP(B*X) HAS MAXIMUM R-SQUARE

EQUATION Y = A + B*X HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

LOS ANGELES AFS

EQUATION A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X 2.84477		1344.10072	-1.74084	69.65523
Y = A + B*X 70.07879	-5.56469	47.58708	0.90296	10.15536
Y = A*EXP(B*X) 68.32399	-0.17538	15.83195	0.96772	9.6[illegible]027
Y = 1/(A + B*X) -0.00242	0.00690	2345.63000	-3.78313	150.72931
Y = A + B/X 15.86586	69.76959	119.23551	0.75686	22.07761
Y = A + B*LOG(X) 79.27051	-27.23472	24.28063	0.95049	11.84988
Y = A*X↑B 105.81370	-0.79287	153.15909	0.68768	33.31370
Y = X/(A + B*X) -0.06305	0.05873	9512.21726	-18.39698	304.20593

EQUATION Y = A*EXP(B*X) HAS MAXIMUM R-SQUARE

EQUATION Y = A*EXP(B*X) HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

LOWRY AFB

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	2.51308		432.90288	-4.25536	36.48692
Y = A + B*X	40.21970	-2.31329	5.85014	0.92898	3.60012
Y = A*EXP(B*X)	43.86079	-0.09385	3.76131	0.95434	3.04776
Y = 1/(A + B*X)	0.01781	0.00409	7.66390	0.90696	6.65928
Y = A + B/X	18.19369	27.02869	26.67043	0.67623	7.39197
Y = A + B*LOG(X)	43.42810	-10.95386	6.97160	0.91537	4.42810
Y = A*X↑B	48.40835	-0.42547	16.09597	0.80460	9.40835
Y = X/(A + B*X)	-0.04014	0.05477	122.16386	-0.48305	29.39855

EQUATION Y = A*EXP(B*X) HAS MAXIMUM R-SQUARE

EQUATION Y = A*EXP(B*X) HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

MARCH AFB

EQUATION A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X 1.72969		525.89269	-1.49085	46.47031
Y = A + B*X 42.53182	-3.37413	48.32843	0.77110	10.56469
Y = A*EXP(B*X) 50.92874	-0.17233	37.88155	0.82058	14.03802
Y = 1/(A + B*X) 0.00268	0.01099	121.66743	0.42373	24.93666
Y = A + B/X 9.36521	43.44450	67.21698	0.68163	19.37366
Y = A + B*LOG(X) 48.22659	-16.58656	38.24356	0.81886	14.36726
Y = A*X↑B 62.78348	-0.79816	76.65023	0.63695	18.83620
Y = X/(A + B*X) -0.11043	0.10268	3266.52624	-14.47163	177.24272

EQUATION Y = A*EXP(B*X) HAS MAXIMUM R-SQUARE

EQUATION Y = A + B*X HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

MAXWELL AFB

EQUATION / A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X 7.20092		1326.00894	-10.82364	65.69908
Y = A + B*X 68.19242	-0.98217	98.35437	0.12300	21.94592
Y = A*EXP(B*X) 67.01128	-0.01437	99.28854	0.11467	20.88419
Y = 1/(A + B*X) 0.01526	0.00021	101.94747	0.09096	20.01380
Y = A + B/X 58.49779	12.84040	99.57739	0.11210	20.34413
Y = A + B*LOG(X) 69.24592	-4.46541	99.61836	0.11173	21.04017
Y = A*X↑B 68.15880	-0.06627	100.30829	0.10558	20.13611
Y = X/(A + B*X) -0.00306	0.01739	101.75358	0.09269	21.79847

EQUATION Y = A + B*X HAS MAXIMUM R-SQUARE

EQUATION Y = 1/(A + B*X) HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

McGUIRE AFB

SELECT BEST FIT

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	3.61738		1687.47536	-2.12700	63.36523
Y = A + B*X	78.61515	-5.81643	55.86505	0.89648	10.28368
Y = A*EXP(B*X)	100.94150	-0.16430	107.84651	0.80015	21.74737
Y = 1/(A + B*X)	-0.00111	0.00545	2979.27286	-4.52078	166.25760
Y = A + B/X	26.44883	55.52765	304.54882	0.43565	25.26925
Y = A + B*LOG(X)	82.90918	-25.27667	138.14452	0.74401	19.00918
Y = A*X↑B	109.65974	-0.69093	366.00049	0.32178	45.75974
Y = X/(A + B*X)	-0.04579	0.04616	672693.14466	-1245.54311	2592.74665

EQUATION Y = A + B*X HAS MAXIMUM R-SQUARE

EQUATION Y = A + B*X HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

OFFUTT AFB

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	2.99123		339.70000	-9.31491	34.50877
Y = A + B*X	35.29697	-1.24441	10.78872	0.67240	5.91935
Y = A*EXP(B*X)	35.96365	-0.04577	10.21356	0.68987	5.84534
Y = 1/(A + B*X)	0.02685	0.00174	9.65088	0.70695	5.99085
Y = A + B/X	22.84008	16.89189	11.17653	0.66063	5.04773
Y = A + B*LOG(X)	37.61310	-6.24685	8.41007	0.74463	5.37081
Y = A*X↑B	38.62506	-0.22150	8.58920	0.73919	5.40609
Y = X/(A + B*X)	-0.02044	0.04343	16.07927	0.51176	5.98[illegible]91

EQUATION Y = A + B*LOG(X) HAS MAXIMUM R-SQUARE

EQUATION Y = A + B/X HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT PATRICK AFB

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	2.04692		700.33188	-1.31928	56.25308
Y = A + B*X	46.98485	-3.59126	117.53182	0.61077	18.[illegible]026
Y = A*EXP(B*X)	[illegible]8.00808	-0.13958	89.43909	0.70381	16.[illegible]609
Y = 1/(A + B*X)	0.01579	0.00700	85.86622	0.71564	17.[illegible]571
Y = A + B/X	8.97896	56.70015	56.82951	0.81180	14.17097
Y = A + B*LOG(X)	56.82568	-19.92314	52.52200	0.82606	15.28147
Y = A*X↑B	65.61225	-0.73225	49.30864	0.83671	12.00380
Y = X/(A + B*X)	-0.08612	0.08355	20206.31813	-65.91700	448.08464

EQUATION Y = A*X↑B HAS MAXIMUM R-SQUARE

EQUATION Y = A*X↑B HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

SCOTT AFB

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	5.62246		1291.52821	-9.83779	60.[illegible]7754
Y = A + B*X	69.60152	-2.72972	12.61429	0.89415	5.61737
Y = A*EXP(B*X)	72.48882	-0.05450	15.43897	0.87044	6.00970
Y = 1/(A + B*X)	0.01283	0.00111	21.67208	0.81814	6.88974
Y = A + B/X	44.69418	27.70350	60.64951	0.49106	12.67994
Y = A + B*LOG(X)	71.74588	-11.94016	29.57696	0.75181	9.10670
Y = A*X↑B	75.02637	-0.23334	38.11710	0.68014	10.00884
Y = X/(A + B*X)	-0.01030	0.02272	85.17221	0.28528	14.66435

EQUATION Y = A + B*X HAS MAXIMUM R-SQUARE

EQUATION Y = A + B*X HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

SHEPPARD AFB

EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	4.48169		1180.68221	-4.43383	56.81831
Y = A + B*X	65.23788	-3.34685	57.10328	0.73719	12.40361
Y = A*EXP(B*X)	67.39723	-0.07443	50.12702	0.76930	10.75718
Y = 1/(A + B*X)	0.01388	0.00173	50.35471	0.76825	12.69347
Y = A + B/X	33.52896	38.49319	104.30449	0.51996	17.64774
Y = A + B*LOG(X)	70.13412	-16.00070	56.39467	0.74046	12.84756
Y = A*X↑B	74.64505	-0.35179	71.68036	0.67011	14.96452
Y = X/(A + B*X)	-0.01904	0.03003	209.46493	0.03598	29.67667

EQUATION Y = A*EXP(B*X) HAS MAXIMUM R-SQUARE

EQUATION Y = A*EXP(B*X) HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT VANDENBERG AFB

EQUATION A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X 3.48277		1069.22195	-3.04363	58.11723
Y = A + B*X 2.72500	-4.04423	30.53359	0.88453	7.76346
Y = A*EXP(B*X) 9.22535	-0.11123	18.51786	0.92997	6.98219
Y = 1/(A + B*X) 0.01047	0.00333	28.02819	0.89400	10.83869
Y = A + B/X 23.83997	48.71417	83.47884	0.68430	14.20294
Y = A + B*LOG(X) 68.91508	-19.49901	25.48988	0.90360	8.96737
Y = A*X↑B 79.11119	-0.51423	58.58449	0.77844	17.51119
Y = X/(A + B*X) -0.03393	0.04092	786.10134	-1.97291	81.46374

EQUATION Y = A*EXP(B*X) HAS MAXIMUM R-SQUARE

EQUATION Y = A*EXP(B*X) HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

SELECT BEST FIT

WRIGHT-PATTERSON AFB

EQUATION / A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X 6.53431		1471.88149	-13.97793	69.96569
Y = A + B*X 74.21364	-2.37133	17.85824	0.81827	8.51434
Y = A*EXP(B*X) 74.90974	-0.03899	14.56318	0.85180	7.91625
Y = 1/(A + B*X) 0.01317	0.00065	12.42977	0.87351	7.36453
Y = A + B/X 50.74984	31.12966	24.38111	0.75190	7.26774
Y = A + B*LOG(X) -9.67520	-11.93275	8.78931	0.91056	6.35514
Y = A*X↑B 80.25740	-0.19357	10.05048	0.89773	5.96828
Y = X/(A + B*X) -0.00802	0.01946	39.22570	0.60084	10.92330

EQUATION Y = A + B*LOG(X) HAS MAXIMUM R-SQUARE

EQUATION Y = A*X↑B HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

APPENDIX H

COMPUTATION OF MEAN ABSOLUTE DEVIATIONS AND TRACKING SIGNALS FOR THE AGGREGATE AND McGUIRE AIR FORCE BASE FOR THE THREE LEARNING CURVE MODELS

McGuire

Learning Curve by Month

MTH	FORECAST	ACTUAL	ACTUAL DEVIATION	RSFE	ABSOLUTE DEVIATION
13	18.6	17.9	-.7	-.7	.7
14	17.7	5.0	-12.7	-13.4	12.7
					13.4

MAD = -13.4/2 = 6.7

T.S.= -13.4/6.7 = -2 MADs

Learning Curve by Unit

MTH	FORECAST	ACTUAL	ACTUAL DEVIATION	RSFE	ABSOLUTE DEVIATION
13	23.5	17.9	-5.6	-5.6	5.6
14	23.0	5.0	-18.0	-23.6	18.0
					23.6

MAD = 23.6/2 = 11.8

T.S.= -23.6/11.8 = -2 MADs

Learning Curve by Best Fit

MTH	FORECAST	ACTUAL	ACTUAL DEVIATION	RSFE	ABSOLUTE DEVIATION
13	3.0	17.9	14.9	14.9	14.9
14	-2.8	5.0	7.8	22.7	7.8
					22.7

MAD = 22.7/2 = 11.4

T.S.= 22.7/11.4 = 2 MADs

Aggregate

Learning Curve by Month

MTH	FORECAST	ACTUAL	ACTUAL DEVIATION	RSFE	ABSOLUTE DEVIATION
13	27.0	26.4	-.6	-.6	.6
14	26.3	24.9	-1.4	-2.0	1.4
					2.0

MAD = 2.0/2 = 1

T.S.=-2/1 = -2 MADs

Learning Curve by Unit

MTH	FORECAST	ACTUAL	ACTUAL DEVIATION	RSFE	ABSOLUTE DEVIATION
13	29.2	26.4	-2.8	-2.8	2.8
14	28.8	24.9	-3.9	-6.7	3.9
					6.7

MAD = 6.7/2 = 3.4

T.S.= -6.7/3.4 = -2 MADs

Learning Curve by Best Fit

MTH	FORECAST	ACTUAL	ACTUAL DEVIATION	RSFE	ABSOLUTE DEVIATION
13	24.4	26.4	2.0	2.0	2.0
14	23.3	24.9	1.6	3.6	1.6
					3.6

MAD = 3.6/2 = 1.3

T.S.= 3.6/1.3 = 2.8 MADs

SELECTED BIBLIOGRAPHY

A. REFERENCES CITED

1. Abernathy, William J. and Kenneth Wayne. "Limits of the Learning Curve," Harvard Business Review, September-October 1974, pp. 109-119.

2. Aeronautical Systems Division, Air Force Systems Command. Contract F-33567-81-C-0359 with Raytheon Company. Wright-Patterson AFB OH, 27 October 1981.

3. Allen, Captain Scott C., USAF and Captain Charles M. Farr, USAF. "An Investigation of the Effect of Production Rate Variation on Direct Labor Requirements for Missile Production Programs." Unpublished master's thesis, LSSR 42-80, AFIT/LSGR, Wright-Patterson AFB OH, 1980. ADA 094446.

4. American Society of Travel Agents, Inc. "A Proposal for Travel Agent Participation in Government Travel Procurement." Washington DC, undated.

5. Andress, Frank J. "The Learning Curve as a Production Tool," Harvard Business Review, January-February 1954, pp. 87-97.

6. Asher, Harold. Cost-Quantity Relationships in the Airframe Industry, R-291. Santa Monica CA: The Rand Corporation, July 1, 1956.

7. Baloff, Nicholas. "Estimating the Parameters of the Startup Model--An Empirical Approach," Journal of Industrial Engineering, April 1967, pp. 248-253.

8. ________. "Startups in Machine-Intensive Production Systems," Journal of Industrial Engineering, January 1966, pp. 25-32.

9. Bateman, Beth. "SATOs Eye Contracts and Boost Services," Travel Weekly, December 14, 1981, pp. 32-33.

10. Bender, Staff Sergeant Anthony R. Traffic Management Specialist, 438th Squadron, 438th Military Airlift Wing, McGuire AFB NJ. Telephone interview. 28 July and 4 August 1982.

11. Bundy, James H. Staff Transportation Officer, Traffic Management Division, Directorate of Transportation, Strategic Air Command, Offutt AFB NE. Telephone interview. 4 August 1982.

12. Chase, Richard B. and Nicholas J. Aquilano. Production and Operations Management, A Life Cycle Approach. 3d ed. Homewood IL: Richard D. Irwin, Inc., 1981.

13. Congleton, Captain Duane E. and Major David W. Kinton. "An Empirical Study of the Impact of a Production Rate Change on the Direct Labor Requirements for an Airframe Manufacturing Program." Unpublished master's thesis, LSSR 23-77B, AFIT/SL, Wright-Patterson AFB OH, 1977. ADA 052720.

14. Crozier, Captain Michael W., USAF, and Captain Edward J. J. McGann, Jr., USAF. "An Investigation of Changes in Direct Labor Requirements Resulting from Changes in Aircraft Engine Production Rate." Unpublished master's thesis, LSSR 22-79B, AFIT/LSGR, Wright-Patterson AFB OH, 1979. ADA 077649.

15. Department of Contracting Management. School of Systems and Logistics, Air Force Institute of Technology (AU). Life Cycle Costing, QMT-353. Wright-Patterson AFB OH, undated.

16. Doak, Major Larry A. Staff Transportation Officer, Passenger Branch, Directorate of Transportation, Headquarters Air Force, Washington DC. Telephone interviews conducted intermittently from 8 October 1981 to 4 August 1982.

17. Executive Office of the President. Office of Management and Budget. Circular No. A-76. Revision 4. 29 March 1979.

18. Freeman, Olen L. Transportation Officer, Traffic Management Office, 3800th Air Base Group, Maxwell AFB AL. Telephone interviews conducted on 3 and 4 August 1982.

19. Hale, Jack R. Assistant Professor of Quantitative Methods, Department of Contracting Management, AFIT/LS, Wright-Patterson AFB OH. Personal interviews conducted intermittently from 21 June to 28 July 1982.

20. Harland, Lieutenant Mark D., USAF. Price Analyst Negotiator, Headquarters Aeronautical Systems Division, Wright-Patterson AFB OH. Personal interview. 24 February 1982.

21. Harris, LeBrone C. and William L. Stephens. "The Learning Curve: A Case Study," Management Accounting, February 1978, pp. 47-52.

22. Hay, William W. An Introduction to Transportation Engineering. 2d. New York: John Wiley and Sons, 1977.

23. Hirschmann, Winfred B. "Profit from the Learning Curve," Harvard Business Review, January-February 1982, pp. 125-139.

24. Leiser, Roland. "Losses Force Chalk From Government Travel Test," Travel Agent, December 24, 1981, p. 16.

25. Lieber, Raymond S. "Production Cost Analysis Using the Underlying Learning Curve." Unpublished master's thesis, New Mexico State University, Las Cruces NM, 1982.

26. Lloyd, R. A. "Experience Curve Analysis," Applied Economics, June 1979, pp. 221-234.

27. McClave, James T. and P. George Benson. Statistics for Business and Economics. Rev. ed. San Francisco CA: Dellen Publishing Company, 1979.

28. McDade, William. Director of Policy Development and Analysis Division, Office of Travel and Management, General Services Administration, Washington DC. Telephone interview. 4 August 1982.

29. "Memorandum of Understanding Between SATO and the 2750th Air Base Wing." 23 April 1981. Memorandum indicating the intent of the parties concerning operation of a SATO at Wright-Patterson AFB OH. Copy obtained from 2750th Logistics Squadron, Traffic Management Office.

30. "Memorandum of Understanding Concerning Scheduled Airlines Traffic Offices (SATOs) at Military Installations in the United States and Puerto Rico." 16 April 1981. Memorandum indicating the intent of the parties concerning the establishment and operation of SATOs or DOD Installations in the United States and Puerto Rico. Copy obtained from 2750th Logistics Squadron, Traffic Management Office.

31. Meyer, Lieutenant Colonel James F. Chief of the Traffic Management Branch, Directorate of Transportation, Headquarters Military Airlift Command, Scott AFB IL. Telephone interviews conducted intermittently from 22 July to 4 August 1982.

32. Meyers, Paul L. Introduction: Probability and Statistical Application. 2d ed. New York: Addison and Wesley, 1970.

33. Military Traffic Management Command. "DOD Travel Management Services Test Plan. Washington DC, undated.

34. ________. "Military Traffic Command Study of DOD Reservation and Ticketing Service." Washington DC, 1 June 1978.

35. Miller, L. H. "Tables of Percentage Points of Kolmogorov Statistics," Journal of the American Statistical Association, Vol. LI (1956), pp. 111-121.

36. O'Hara, Barbara E. Director, Government Affairs, American Society of Travel Agents, Inc. Telephone interview. 12 April 1982.

37. Pichon, Captain Allen A., Jr., USAF and Captain Charles L. Richardson, USAF. "The Development of a Predictive Model for First Unit Costs Following Breaks in Production." Unpublished master's thesis, SLSR 15-74B, AFIT/LSGR, Wright-Patterson AFB OH, 1974. AD 785953.

38. Plossl, G. W. and O. W. Wight. Production and Inventory Control, Principles and Techniques. Englewood Cliffs NJ: Prentice-Hall, Inc., 1967.

39. Reagan, Ronald. President, United States of America. Letter, subject: Strengthening Federal Travel Management, to Heads of Executive Departments and Agencies, 30 July 1981.

40. Request for Proposal. Travel Management Services to arrange for transportation and other travel services for Travis AFB personnel performing official government travel, collect and provide related management data, and provide travel services for other personnel on vacation/leave travel. F04626-82-R0044. Travis Air Force Base CA: Base Contracting Division, 60 MAW/LCC. Effective 7 July 1982.

41. Riggin, Aden. Director of Military and Government Transportation Services, Air Traffic Conference of America, Washington DC. Telephone interview. 28 October 1981.

42. Schoderbek, Charles G., Peter P. Schoderbek, and Asterios G. Kefalas. Management Systems, Conceptual Considerations. Dallas TX: Business Publications, Inc., 1980.

43. Selzer, Colonel Franklin J. Chief of Passenger Branch, Directorate of Transportation, Headquarters Air Force, Washington DC. Telephone interview. 23 August 1981.

44. Shannon, Robert E. Systems Simulation, The Art and Science. Englewood Cliffs NJ: Prentice-Hall, Inc., 1975.

45. Smith, Lieutenant Colonel Larry L., USAF. "An Investigation of Changes in Direct Labor Requirements Resulting from Changes in Airframe Production Rate." Unpublished doctoral dissertation, Department of Marketing, Transportation and Business Environment, University of Oregon, Eugene OR, 1976. AD 0926112.

46. Stevens, Captain David Y. and Captain Jimmie Thomerson. "An Investigation of Changes in Direct Labor Requirements Resulting from Changes in Avionics Production Rate." Unpublished master's thesis, LSSR 11-79A, AFIT/SL, Wright-Patterson AFB OH, 1979. ADA 077725.

47. Thompson, Michael. Scheduled Airline Traffic Office Manager, Wright-Patterson AFB OH. Personal interviews conducted intermittently from 27 October 1981 to 3 August 1982.

48. "TMO/SATO Interface Test Program Briefing." Attached to Letter, Arthur A. Hemmings to Western Area Transportation Conference, subject: MTMCWA Air Force Talk or Presentations, October 1980.

49. Trimble, Robert F. "Social and Economic Programs and the Federal Procurement Process," NCMA Journal, May 1977, pp. 11-14.

50. U.S. Congress. U.S. Senate. Committee on Governmental Affairs. Hearings on Federal Travel Management. Hearings, 97th Congress, 1st Session, 1981. Washington: Government Printing Office, 1981.

51. U.S. Department of Defense. Joint Travel Regulation. Volume I: "Members of the Uniformed Services." Washington: Government Printing Office, 1980.

52. ________. Office of the Deputy Assistant Secretary of Defense. "Report on the Ad Hoc Working Group on the Framework for Reservation and Ticketing Services (FRATS)." Unpublished research report, unnumbered. Copy obtained from Passenger Directorate, HQ MTMC/MTPTP.

53. U.S. Department of Labor, Employment and Training Administration. Memorandum for Evaluation Committee, ETA Travel Agent Experiment, Washington, 1981.

54. U.S. General Accounting Office. Air Force C-130 Contract Price is Overstated and Proper Action Has Not Been Taken to Improve Lockheed's Cost Accounting and Estimating Systems. PSAD-80-69, Washington DC: Government Printing Office, 1980.

55. ________. Use of Discount Airline Fares and Teleticketing Would Help Save on Government Travel Expenses. FGMSD-78-46. Washington DC: Government Printing Office, 1978.

56. Velocci, Tony. "Pentagon, Can It Cut Waste?" Nation's Business, March 1982, pp. 22-24,26,28.

57. Walker, Winfred M., Jr. Traffic Management Specialist, Passenger Directorate, Military Traffic Management Command, Bailey's Crossroads VA. Telephone interviews conducted intermittently from 15 October 1981 to 25 June 1982.

58. Wright, T. P. "Factors Affecting the Cost of Airplanes," Journal of the Aeronautical Science, February 1936, pp. 122-128.

59. Yelle, Louis E. "The Learning Curve. Historical Review and Comprehensive Survey," Decision Sciences, April 1979, pp. 302-328.

B. RELATED SOURCES

"Agents Win New Status," Travel Weekly, February 15, 1982, p. 15.

Alchian, Armen A. and William R. Allen. University Economics. Belmont CA: Wadsworth Publishing Company, Inc., 1964.

Cochran, E. B. Planning Production Costs: Using the Improvement Curve. San Francisco CA: Chandler Publishing Company, 1968.

Conway, R. W. and Andrew Schultz, Jr. "The Manufacturing Progress Function," Journal of Industrial Engineering, January-February 1959, pp. 39-54.

Department of Contracting Management. Cost and Price Analysis Division, School of Systems and Logistics, Air Force Institute of Technology (AU). Computer Programs for QMT 550 and QMT 551. Wright-Patterson AFB OH, undated.

Executive Office of the President. Office of Management and Budget. Report on Strengthening Federal Travel Management. Washington: Government Printing Office, 1981.

Fabrycky, W. J. and P. E. Torgersen. Operations Economy: Industrial Applications of Operations Research. Englewood Cliffs NJ: Prentice-Hall, 1966.

"Feds' Advice on Government Travel: Work Out Pay," Travel Weekly, January 28, 1982, p. 26.

Goodman, Major William I., USAF. Chief, Business Strategy Division, AFALD, Headquarters Air Force Logistics Command, Wright-Patterson AFB OH. Telephone interview. 23 February 1982.

"Government is Urged to Compensate Retailers," Travel Weekly, December 17, 1981, p. 14.

"Government Reports Savings on Fares," Travel Weekly, February 15, 1982, p. 10.

"GSA is Extending Deadline on Bids on Travel Accounts," Travel Weekly, February 1, 1982, p. 42.

"GSA Opens Bids to Retailers Because of Revised Definition," Travel Weekly, February 15, 1982, p. 19.

Harrity, Gail M. American Society of Travel Agents, Inc. Letter, subject: GAO Prohibitions on Using Commercial Travel Agents to Procure Transportation Services for Federal Employees, 12 January 1979.

Large, Joseph P., Karl Hoffmayer, and Frank Kentrovich. "Production Rate and Production Cost." Unpublished research report No. R-1609-PA&E, The Rand Corporation, Santa Monica CA, 1974.

Levenson, G. S. and S. M. Barro. Cost-Estimating Relationships for Aircraft Airframes, RM-4845-PR, The Rand Corporation, Santa Monica CA, February 1966.

Lieber, Raymond S. Industrial Engineer, Manufacturing, Deputy for Propulsion, Headquarters Aeronautical Systems Division, Wright-Patterson AFB OH. Personal interview. 1 July 1982.

Meulenberg, M. T. G. "On the Estimation of an Exponential Function," Econometrica, October 1965, pp. 863-868.

"Missouri Retailer is Awarded One-Year Contract from GSA," Travel Weekly, April 22, 1982, pp. 1,63.

Morse, Stella M. Chief of Passenger and Personal Property Section, Traffic Management Office, 416 Bombardment Wing, Griffiss AFB NY. Telephone interviews. 2 and 3 August 1982.

Orsini, Joseph A. "An Analysis of Theoretical and Empirical Advances in Learning Curve Concepts Since 1966." Unpublished master's thesis, GSA/SM/70-12, AFIT/SM, Wright-Patterson AFB OH, 1970.

"Reduced Airline Fares--AFISC," TIG Brief, November 1978, p. 4

Request for Proposal. Travel Management Services to Arrange for Transportation and Other Travel Services for Department of Defense personnel performing official Government travel, collect and provide related management data, and provide travel services for Department of Defense personnel on vacation/leave travel. Copy obtained from Passenger Directorate, HQ MTMC/MTPTP, undated.

Scherer, John D., ed. "Learning Curve Analysis." Department of Special Management Techniques, AFIT/SL, Wright-Patterson AFB OH, 1976.

Shadowens, Gene. Chief, Passenger Section, Traffic Management Office, 2750th Logistics Squadron, Wright-Patterson AFB OH. Personal interview. 27 October 1981.

Shroad, Vincent J. "Control of Labor Costs Through the Use of Learning Curves," NAA Bulletin, October 1964, pp. 18-20.

Staats, Elmer B. Comptroller General of the United States. Letter, subject: Individual Agencies may Request GAO to Lift its Prohibition on the Use of Commercial Travel Agents for Government Travel, to Heads of all Departments, Agencies, and others concerned, 20 August 1979.

Tektronix, Inc. Plot 50, Statistics. Volume I. Beaverton OR: Tektronix, Inc., 1975.

Widing, J. William. Project Director. "A Study of DOD Organization and Traffic Management." Boston MA: Harbridge House, Inc., 1980.

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